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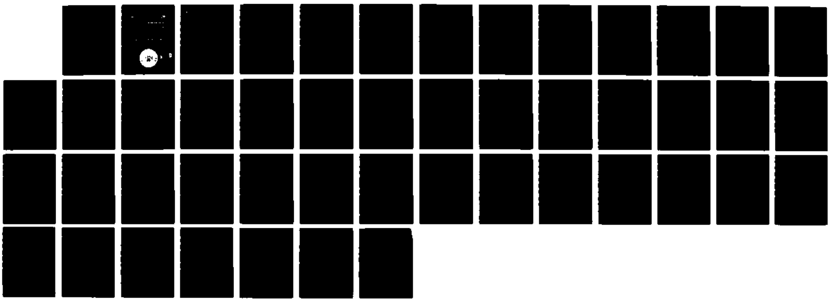

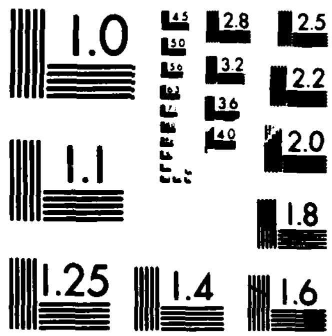
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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 3-86

UNMANNED EVALUATION OF FIVE CARBON DIOXIDE ABSORBENTS WHICH WERE FROZEN PRIOR TO USE WITH THE DRAEGER LAR V UBA

CLARK G. PRESSWOOD

DECEMBER 1986

NAVY EXPERIMENTAL DIVING UNIT

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

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canister duration	AGASORB	Draeger LAR V UBA
carbon dioxide absorbent	DIVEASORB	NAVSEA TA 82-15
oxygen	DRAEGERSORB	NEDU Test Plan 83-22
underwater breathing apparatus (UBA)	PROTOSORB	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Five commercially available carbon dioxide (CO_2) absorbents were evaluated using the Draeger LAR V Underwater Breathing Apparatus (UBA) in the unmanned mode by the Navy Experimental Diving Unit in accordance with NAVSEA Task Assignment 82-15. The purpose of the task was to provide performance data on CO_2 absorbents which had been subjected to low temperatures prior to use to determine which absorbents could be safely utilized by military divers after storage in sub-freezing environments. (over)

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CO_2 absorbent canister duration tests were conducted using a hyperbaric breathing simulator at a depth of 25 feet of sea water (FSW) at a ventilation rate of 23 to 50 liters per minute and at water temperatures of 29°, 35° and 40°F. The performances of the absorbents which were frozen prior to the test were compared to the performances of absorbents stored at room temperature, tested under the same conditions.

The results of unmanned performance testing revealed that subjecting absorbent material to freezing temperatures prior to use did not substantially effect canister duration times in four of the five brands tested. Of the five, only PROTOSORB showed marked performance degradation as a result of freezing. The relative ranking, from the longest to the shortest frozen canister duration time, revealed AGASORB as the best performer. Frozen DRAEGERSORB and PROTOSORB had similar duration times, followed by HP SODASORB and finally DIVEASORB which displayed the poorest performance.

Table of Contents

Glossary

AG	AGASORB
BPM	breaths per minute
Canister Breakthrough	point at which CO_2 concentration in the inhaled gas reached 0.50 percent surface equivalent value (SEV)
°C	temperature degrees centigrade
CmH_2O	centimeters of water pressure
CO_2	carbon dioxide gas
DS	DRAEGERSORB
DV	DIVEASORB
EDF	Experimental Diving Facility Hyperbaric Chamber Complex
°F	temperature degrees Fahrenheit
FSW	feet-of-seawater
HP SODASORB	high-performance SODASORB
kg·m/ℓ	kilogram-meters per liter (respiratory work)
ℓtv	the liter-tidal volume of air breathed in and out of the lungs during normal respiration
ℓpm	liters per minute (flow rate)
NAVSEA	Naval Sea Systems Command
NEDU	Navy Experimental Diving Unit
O_2	oxygen gas
ΔP	pressure differential (cmH_2O)
PR	PROTOSORB
psid	pounds per square inch differential
psig	pounds per square inch gauge
RMV	respiratory-minute-volume in liters-per-minute

Glossary (continued)

SCUBA	self-contained underwater breathing apparatus
SEV	surface equivalent value
SI	System International (units of measure)
TEMP	temperature
Texp	exhaled gas temperature
Tin	inspired gas temperature
UBA	underwater breathing apparatus
U/W	underwater

SI Unit Conversion Table

To Convert From	To	Multiply By
Kg·m/ℓ	joule per liter (J/L)	9.807
psi	kilopascal (kPa)	6.895
°C	kelvin (K)	°K = °C + 273.15
°F	kelvin (K)	°K = (°F + 459.67)/1.8
FSW	meters of seawater (MSW)	0.305
FSW	kilopascal (kPa)	3.065

Abstract

Five commercially available carbon dioxide (CO_2) absorbents were evaluated using the Draeger LAR V Underwater Breathing Apparatus (UBA) in the unmanned mode by the Navy Experimental Diving Unit in accordance with NAVSEA Task Assignment 82-15. The purpose of the task was to provide performance data on CO_2 absorbents which had been subjected to low temperatures prior to use to determine which absorbents could be safely utilized by military divers after storage in sub-freezing environments.

CO_2 absorbent canister duration tests were conducted using a hyperbaric breathing simulator at a depth of 25 feet of sea water (FSW) at a ventilation rate of 23 to 50 liters per minute and at water temperatures of 29°, 35° and 40°F. The performances of the absorbents which were frozen prior to the test were compared to the performances of absorbents stored at room temperature, tested under the same conditions.

The results of unmanned performance testing revealed that subjecting absorbent material to freezing temperatures prior to use did not substantially effect canister duration times in four of the five brands tested. Of the five, only PROTOSORB showed marked performance degradation as a result of freezing. The relative ranking, from the longest to the shortest frozen canister duration time, revealed AGASORB as the best performer. Frozen DRAEGERSORB and PROTOSORB had similar duration times, followed by HP SODASORB and finally DIVEASORB which displayed the poorest performance.

KEY WORDS:

breathing machine
canister duration
carbon dioxide absorbent
oxygen
underwater breathing apparatus (UBA)
frozen
AGASORB
DIVEASORB
DRAEGERSORB
PROTOSORB
HP SODASORB
Draeger LAR V UBA
NAVSEA TA 82-15
NEDU Test Plan 83-22

I. INTRODUCTION

NAVSEA Task Assignment 82-15 directed NEDU to conduct an investigation to determine degradation of CO_2 absorbents when exposed to low temperatures prior to use in a UBA. The W.R. Grace SODASORB Manual specifies that SODASORB which has been exposed to sub-freezing temperatures should be discarded. However, as the possibility exists that HP SODASORB or other CO_2 absorbents could be stored by military divers in a below-freezing environment, this evaluation of various absorbents was conducted.

The moisture content of those commercially available CO_2 absorbents which are the subject of this report range from as low as 11.7% (DRAEGERSORB) to as high as 20.1% (DIVEASORB). When water in a CO_2 absorbent is frozen, it will expand, possibly fragmenting the absorbent granules. A resulting increase in absorbent surface area would, in theory, increase CO_2 scrubbing effectiveness. However, because the porosity of the absorbent is strictly controlled during production, a change in porosity as a result of freezing might decrease CO_2 absorbent effectiveness.

Five commercially available absorbents were tested unmanned in the Draeger LAR V UBA in the NEDU Experimental Diving Facility (EDF). Each material (HP SODASORB, DIVEASORB, AGASORB, PROTOSORB and DRAEGERSORB) was tested to determine the maximum duration of the CO_2 absorbent at a depth of 25 FSW at water temperatures of 29°, 35° and 40°F and a ventilation rate of 23 and 50 liters per minute. Manufacturer's addresses are contained in APPENDIX A. Performance of the absorbents frozen prior to the test were compared to the performance of unfrozen absorbents stored at room temperature, tested under the same conditions.

II. EQUIPMENT

A. Draeger LAR V UBA

1. Functional Description. The functional description of the Draeger LAR V UBA is illustrated in Figure 1. From the oxygen (O_2) cylinder (1), high-pressure O_2 passes through the cylinder on/off valve (2) to the pressure reducing regulator (3) where the high-pressure gas is reduced to a working pressure of 66 psig over-bottom setting, then piped to the demand regulator (4) which is adjustable from 10 to 30 cmH_2O cracking pressure. High-pressure gas is also piped to the 0 to 300 kp/cm^2 (0 to 4410 psig) pressure gauge located on top of the equipment case housing. The demand regulator, secured to the equipment case housing and fitted to the breathing bag (5), functions each time the bag is emptied on inhalation. The inhalation check valve (6) opens on inhalation and the diver receives gas from the breathing bag. If not enough gas is available, the demand valve actuates, adding more oxygen to the system. As the diver exhales, the exhalation check valve (7) opens, the inhalation check valve closes and the exhaled gas flows through the exhalation hose (8) to the CO_2 scrubber; it is then filtered through the CO_2 scrubber (9) with the next inhalation. During descent, or to purge the unit, the diver merely depresses the demand bypass valve in the front center of the case housing.

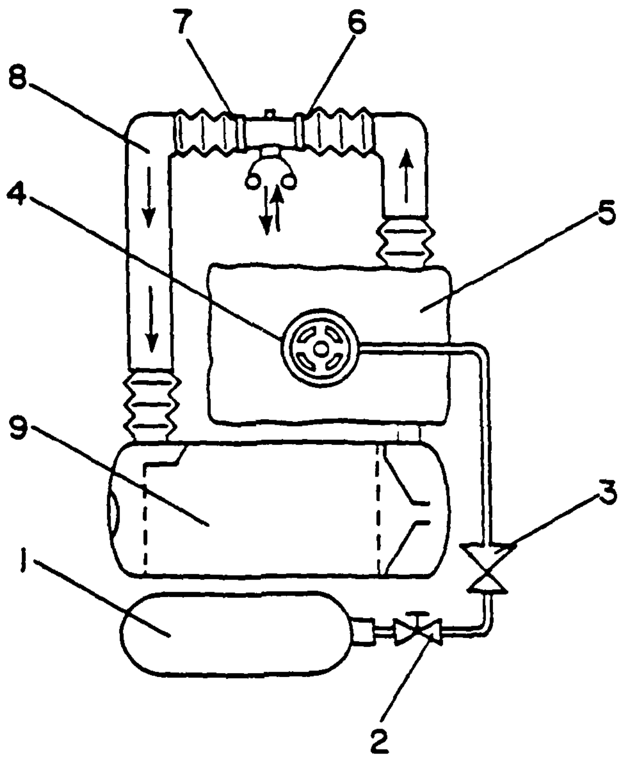


Figure 1. Functional Schematic

2. Specifications. Specifications for the Draeger LAR V UBA are provided below:

Dimensions: 11.8 in. x 16.7 in. x 6.7 in.
Weight: 24.2 lbs.
O_2 cylinder capacity: 10.6 ft^3 @ 3000 psig
CO_2 canister capacity: 5.0 lbs.
CO_2 canister material: fiberglass
Harness design: front mounted, neck and waist straps
Breathing bag volume: 6 liters
O_2 supply pressure gauge: mounted on top of case
Manual O_2 bypass valve: front mounted on case
Oxygen add system type: demand valve, automatically actuated

B. CO2 Absorbents. Appendix B provides CO_2 absorbent specifications.

C. Test Equipment. Appendix C lists the test equipment illustrated in Figure 2.

III. TEST PROCEDURE

A. Test Plan. Appendix D provides the test plan. The CO_2 absorbent canister was packed and placed in a freezer at 20°F for 24 hours prior to each test. The LAR V was then quickly submerged in the thermally controlled wetbox (ark) in EDF Chamber C. The time from removing the frozen canister from the freezer to commencing the test was a maximum of 15 minutes. A breathing machine was used to simulate diver respiration while EDF Chamber C was used to maintain diver depth.

B. Controlled Parameters. Canister duration controlled parameters included the following:

1. Standardized CO_2 add rates and exhaled gas temperatures were controlled as set forth in NEDU Report 3-81 (reference 1).

2. Water TEMP: 29°, 35° and 40°F.

3. Depth: 25 FSW.

4. LAR V breathing gas: pure O_2.

5. O_2 supply pressure: 1000 psig.

6. Relative humidity of exhaled gas: 90 (±2)%.

7. Canister packing density: canister duration in any UBA is sensitive to how the absorbent is packed. Consequently, great care was taken to assure conformity of canister packing at ±4 ounces in order to achieve consistent results.

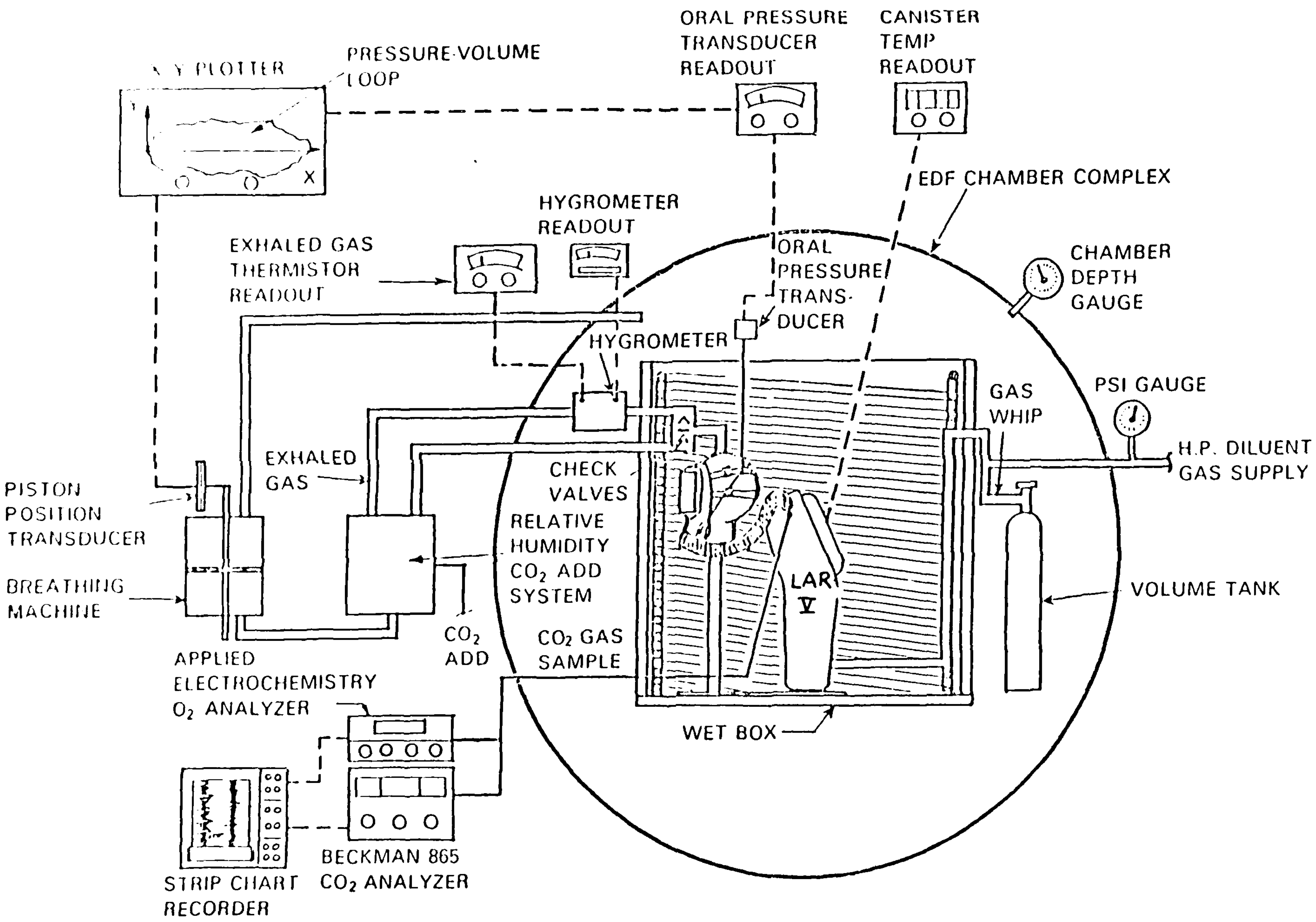


FIGURE 2 - TEST SETUP

8. Brands of absorbent material: HP SODASORB, DIVEASORB, AGASORB, PROTOSORB and DRAEGERSORB.

9. Canister temperature: canisters packed with CO_2 absorbent were frozen for 24 hours in a freezer set at 20°F.

C. Measured Parameters

1. CO_2 (% SEV) levels at absorbent canister inlet and outlet.

2. Canister bed temperature (3 ea) in °F. Location of canister bed thermistors is provided in Appendix G, Figure 43.

D. Computed Parameter. Exhaled gas TEMP was calculated and controlled as a function of water temperature based on the standardized procedure set forth in NEDU Report 3-81 (reference 1).

E. Data Plotted

1. The following plots were developed from data obtained:

a. Times at which CO_2 levels (% SEV) reach 0.5 and 0.9% SEV CO_2 vs. all water temperatures under each test condition, provided as Appendix E (Figures 3 through 12).

b. Canister outlet CO_2 levels (% SEV) vs. time (hours), provided as Appendix F (Figures 13 through 27).

c. Canister bed temperature (°F) from three locations vs. time (hours), provided as Appendix G (Figures 28 through 42).

2. Two tests at each water temperature with each CO_2 absorbent was conducted with absorbents frozen prior to use, plotting the various data listed above. Five CO_2 absorbents tested at three water temperatures resulted in a total of 30 unmanned test dives with the Draeger LAR V UBA using the frozen absorbents. Results are provided in mean times which represent the average of two tests conducted.

IV. RESULTS

A. Frozen CO2 Absorbent Canister Duration Tests. Tables 1 and 2 and Appendix E (Figures 3 through 12) compare frozen and non-frozen canister duration test results for the same test conditions at each temperature tested. The following is a summary of results:

1. HP SODASORB: frozen canister performance was comparable to the performance of non-frozen canisters.

2. DIVEASORB: frozen canister performance was comparable to the performance of non-frozen canisters. DIVEASORB provided the shortest duration times of all the CO_2 absorbents tested, frozen or non-frozen.

3. AGASORB: frozen canister performance was slightly better than the performance of non-frozen canisters. AGASORB provided the longest duration times of all CO_2 absorbents tested.

4. PROTOSORB: freezing notably degraded canister performance, particularly at the 35° and 40°F test temperatures. It should be noted, however, that at the same test temperatures, PROTOSORB's "degraded" duration times were twice as long as DIVEASORB's best duration times.

5. DRAEGERSORB: frozen canister performance was comparable to non-frozen canister performance at 35°F, somewhat degraded at 40°F, and notably improved at the 29°F test temperature.

B. Comparative Results. A relative comparison of the five tested CO_2 absorbents was conducted. By comparing all the frozen canister duration time test results, the following relative ranking, from the longest to the shortest duration, was derived by computing mean time for each absorbent at all temperatures, and by ranking each absorbent at each temperature and averaging the rank.

1. AGASORB

2. DRAEGERSORB

3. PROTOSORB

4. HP SODASORB

5. DIVEASORB

Previous unmanned testing of the five CO_2 absorbents discussed herein in the Draeger LAR V UBA reported by reference 2 provided closely comparable non-frozen canister duration times and the same canister duration performance rankings, except that PROTOSORB outperformed DRAEGERSORB in the previous non-frozen testing.

V. DISCUSSION

Tables 1 and 2 verify that, except for PROTOSORB, subjecting CO_2 absorbent materials to 20°F temperatures for 24 hours did not detrimentally affect canister duration times.

The most notable exceptions occurred during PROTOSORB testing at 35° and 40°F. One of the PROTOSORB frozen canister duration times decreased by 40 minutes (e.g., a frozen canister time of 106 minutes vice the non-frozen canister time of 146 minutes at 40°F, 0.5% SEV CO_2). Additionally, at 29°F DRAEGERSORB lasted 32 minutes longer (to 0.5% SEV CO_2) when the canister was frozen. For absorbents other than PROTOSORB and DRAEGERSORB, variations in frozen canister and non-frozen canister duration times were generally 20 minutes or less, except for HP SODASORB at 35°F (to 0.5% SEV CO_2) which lasted 26 minutes longer when the canister was frozen.

Table 1

LAR V Canister Duration Times for
Frozen and Non-Frozen Canisters to 0.5% SEV CO_2

Absorbent	Mean Time to 0.5% SEV CO2 (min)					
	Temperature					
	29		35		40	
	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen
HP SODASORB	55	61	91	65	95	107
DIVEASORB	28	32	52	63	57	58
AGASORB	108	112	145	127	159	150
PROTOSORB	71	88	117	153	106	146
DRAEGERSORB	83	51	105	108	105	127

Table 2

LAR V Canister Duration Times for
Frozen and Non-Frozen Canisters to 0.9% SEV CO_2

Absorbent	Mean Time to 0.9% SEV CO2 (min)					
	Temperature					
	29		35		40	
	Frozen	Non-Frozen	Frozen	Non-Frozen	Frozen	Non-Frozen
HP SODASORB	73	81	113	107	130	127
DIVEASORB	39	41	66	78	75	76
AGASORB	131	138	167	148	178	176
PROTOSORB	92	110	137	178	126	164
DRAEGERSORB	113	72	131	132	137	*

* Tests not completed

NOTE: Mean canister duration times represent the average of two tests conducted under identical conditions where canister durations were always within 20 minutes of each other.

VI. CONCLUSIONS

With the exception of PROTOSORB, the performance of frozen and non-frozen canisters for the same CO_2 absorbent were very similar. Although detrimental effects of freezing were evident with PROTOSORB, this absorbent still provided canister duration times as good as or longer than those provided by HP SODASORB. AGASORB performed best, having the longest frozen canister duration times, while DIVEASORB exhibited extremely short durations both frozen and non-frozen.

Based on these results AGASORB, DRAEGERSORB, PROTOSORB and HP SODASORB display acceptable performance when used after being frozen at 20°F for 24 hours.

VII. REFERENCES

1. Standardized NEDU Unmanned UBA Test Procedures and Performance Goals; NEDU Report 3-81, J. R. Middleton and E. D. Thalmann.

2. Unmanned Evaluation of Six Carbon Dioxide Absorbents with the Draeger LAR V UBA; NEDU Report 4-85, J. R. Middleton and J. S. Keith.

3. NEDU Test Plan 83-22.

APPENDIX A

LIST OF MANUFACTURER ADDRESSES

Absorbent: AGASORB

Manufacturer: MP United Drug Co., Ltd.
Mill End Thaxted Essex CM6 2LT
Tel: Thaxted (0371) 830676
Telex: 817133 MPUDCO G

Distributor: AGA SPIRO AB
S-181 81 Lidingo, Sweden
Tel 08-731-1211

Absorbent: PROTOSORB

Manufacturer: MP United Drug Co., Ltd.
Mill End Thaxted Essex CM6 2LT
Tel: Thaxted (0371) 830676
Telex: 817133 MPUDCO G

Distributor: SIEBE Gorman & Co. LTD, UK

Absorbent: DRAEGERSORB

Manufacturer: Draegerwerk AG Lubeck
Diving Technics
POSTFACH 1339
Moislinger Allee 53/45
Lubeck 24
Federal Republic of Germany

Absorbent: HP SODASORB

Manufacturer: W.R. Grace & Co.
5225 Phillip Lee Drive, SW
Atlanta, Georgia 30336

Absorbent: DIVEASORB

Manufacturer: Allied Healthcare Products, Inc.
1720 Sublette Avenue
St. Louis, Missouri 63110

APPENDIX B

ABSORBENT MATERIAL SPECIFICATION

A. AGASORB

Sodalime
Non-indicating
8-12 Mesh
16.9 - 17.9% Moisture Content

B. PROTOSORB

Sodalime
Non-indicating
8-12 Mesh
17.4 - 18.7% Moisture Content

C. DRAEGERSORB

Sodalime
With Indicator
Medium Grain (approximately 8-12 mesh)
11.7 - 16.9% Moisture Content

D. HP SODASORB

Sodalime
Ethyl Violet Indicator
4-8 Mesh
14.3 - 16.2% Moisture Content

E. DIVEASORB

Barilyme
Ethyl Violet Indicator
4-8 Mesh
18.2 - 20.1% Moisture Content

APPENDIX C

TEST EQUIPMENT

1. Breathing machine.
2. VALIDYNE DP-15 pressure transducer w/1..00 psid diaphragm (oral pressure).
3. T&E arc.
4. EDF cooling system to control water temperature during canister duration tests.
5. MFE Model 715M X-Y plotter.
6. VALIDYNE CD-19 transducer readout.
7. External O_2 pressure gauge.
8. Chamber depth gauge.
9. Test UBA: Draeger LAR V.
10. Sodalimes (AGASORB, HP SODASORB, PROTOSORB, DIVEASORB, DRAEGERSORB).
11. Breathing machine/piston position transducer/CO_2 and humidity-add system.
12. Relative humidity sensor.
13. Strip chart recorder.
14. Thermistor for inhaled gas temperature.
15. DIGITEC HT-5820 thermistor readouts.
16. BECKMAN 865 infrared analyzers for monitoring CO_2 out of the scrubber.
17. HEWLETT-PACKARD Model HP 1000 computer system.
18. Freezer to pre-chill canisters and CO_2 absorbents.
19. Thermistor for monitoring arc water temperatures.
20. Thermistors for monitoring canister bed temperatures (3 ea).

APPENDIX D

TEST PLAN

1. Fill LAR V canister with HP SODASORB and place in freezer set at 20°F for 24 hours before testing.

2. Insure that LAR V UBA is set up to factory specifications and is working properly. Then quickly (within 15 minutes) place frozen HP SODASORB canister in UBA and connect UBA to unmanned test facility.

3. Chamber is on surface.

4. Calibrate transducers and CO_2 analyzers.

5. Open make-up supply valve to test UBA.

6. Water temperature: 29°F.

7. Start humidity add system.

8. Pressurize chamber to 25 FSW.

9. Start CO_2 add and maintain following procedure until 0.9% SEV CO_2 is reached:

   4 minutes at 0.9 ℓpm CO_2 add/2.0ℓ tidal volume and 11.5 BPM
   6 minutes at 2.0 ℓpm CO_2 add/2.0ℓ tidal volume and 25 BPM

10. Take data every 10 seconds until breakthrough.

11. Repeat steps 1 through 10 at 35° and 40°F respectively.

12. Repeat steps 1 through 11 using PROTOSORB, AGASORB, DRAEGERSORB and DIVEASORB.

APPENDIX E

CANISTER DURATION DATA

Times at which CO_2 levels (% SEV) reach 0.5 and 0.9% SEV CO_2 vs. all water temperatures under each test condition. A comparison of both frozen and non-frozen canister duration test results for each absorbent is contained in this appendix.

KEY:

Figure 3: HP SODASORB (.5% SEV CO_2)

Figure 4: DIVEASORB (.5% SEV CO_2)

Figure 5: AGASORB (.5% SEV CO_2)

Figure 6: PROTOSORB (.5% SEV CO_2)

Figure 7: DRAEGERSORB (.5% SEV CO_2)

Figure 8: HP SODASORB (.9% SEV CO_2)

Figure 9: DIVEASORB (.9% SEV CO_2)

Figure 10: AGASORB (.9% SEV CO_2)

Figure 11: PROTOSORB (.9% SEV CO_2)

Figure 12: DRAEGERSORB (.9% SEV CO_2)

FIG.3 DRAEGER LAR V CANISTER CO2 DURATION TEST
H. P. SODASORB (.5% SEV CO2)

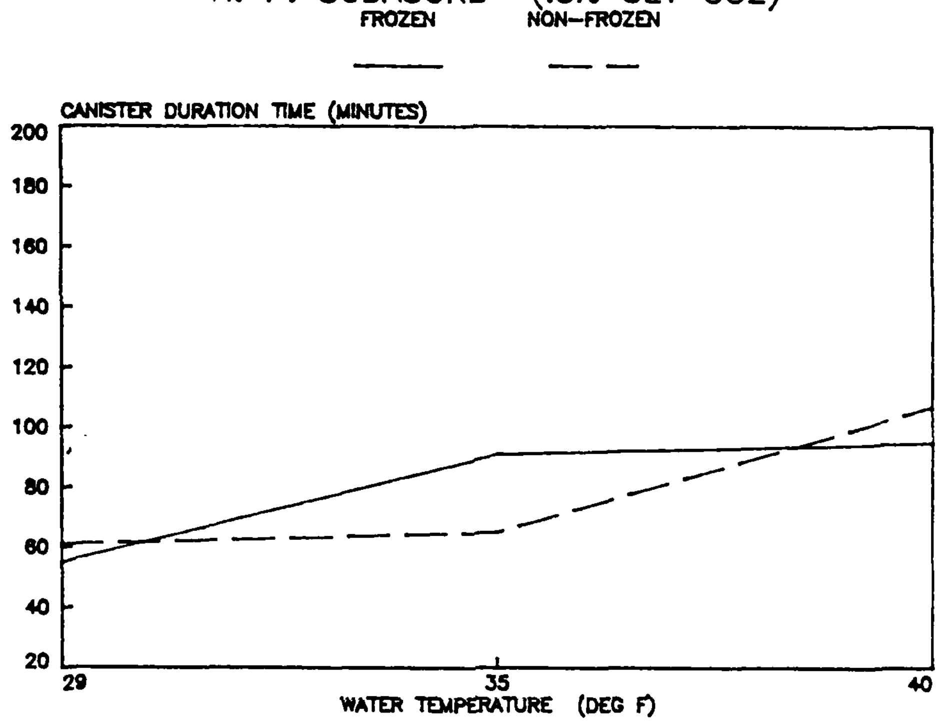


FIG.4 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
DIVE-A-SORB (.5% SEV CO2)

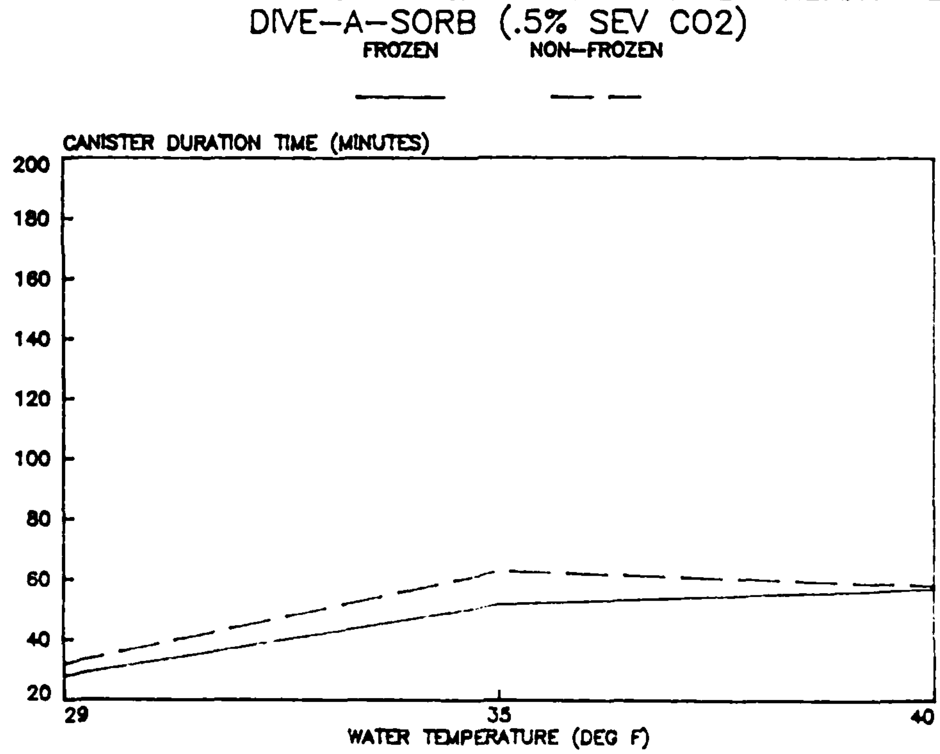


FIG.5 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
AGASORB (.5% SEV CO2)

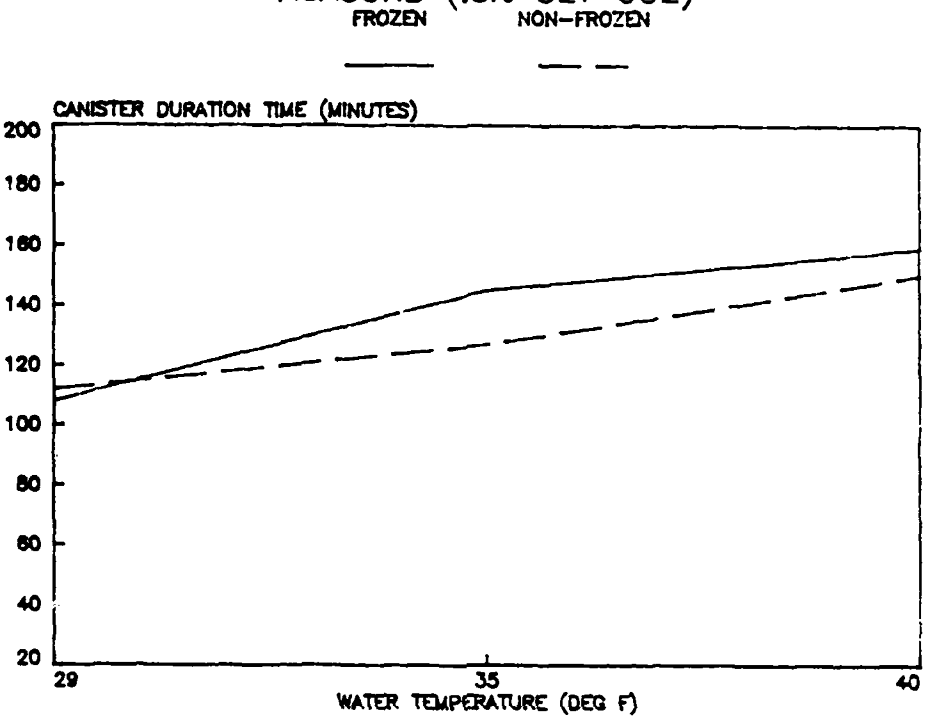


FIG.6 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
PROTOSORB (.5% SEV CO2)

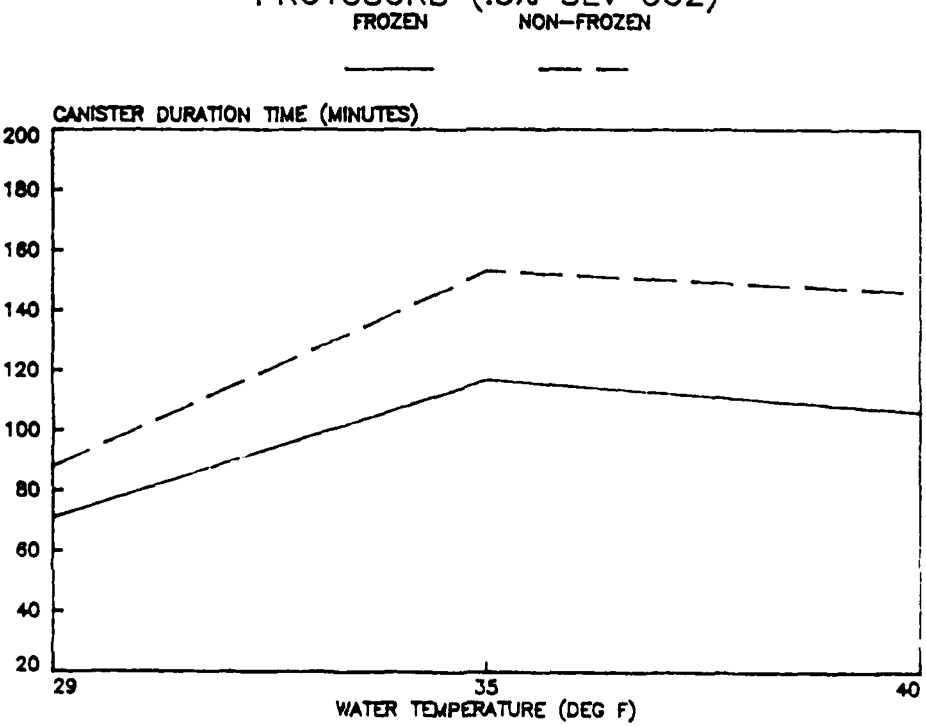


FIG.7 DRAEGER LAR V CANISTER CO2 DURATION TEST
DRAEGERSORB (.5% SEV CO2)

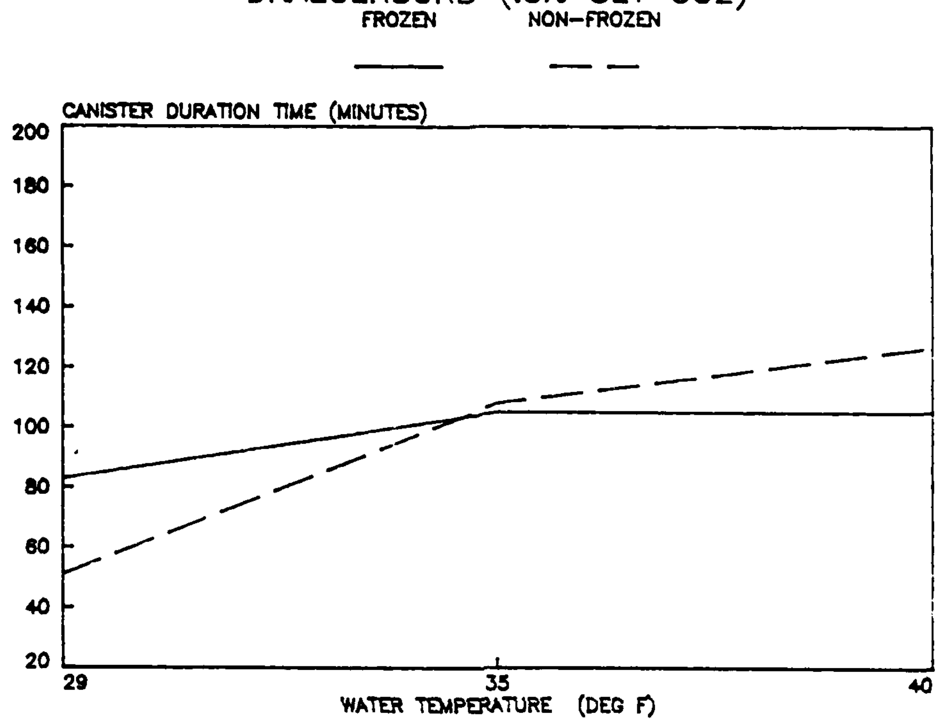


FIG.8 DRAEGER LAR V CANISTER CO2 DURATION TEST
H. P. SODASORB (.9% SEV CO2)

FROZEN ——— NON-FROZEN — —

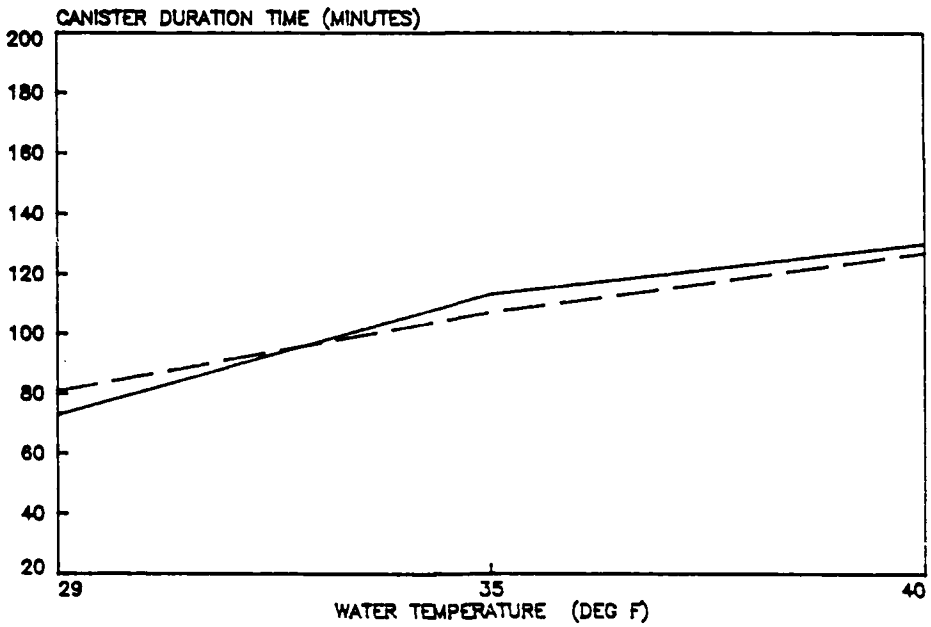


FIG.9 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
DIVE-A-SORB (.9% SEV CO2)

FROZEN ——— NON-FROZEN — —

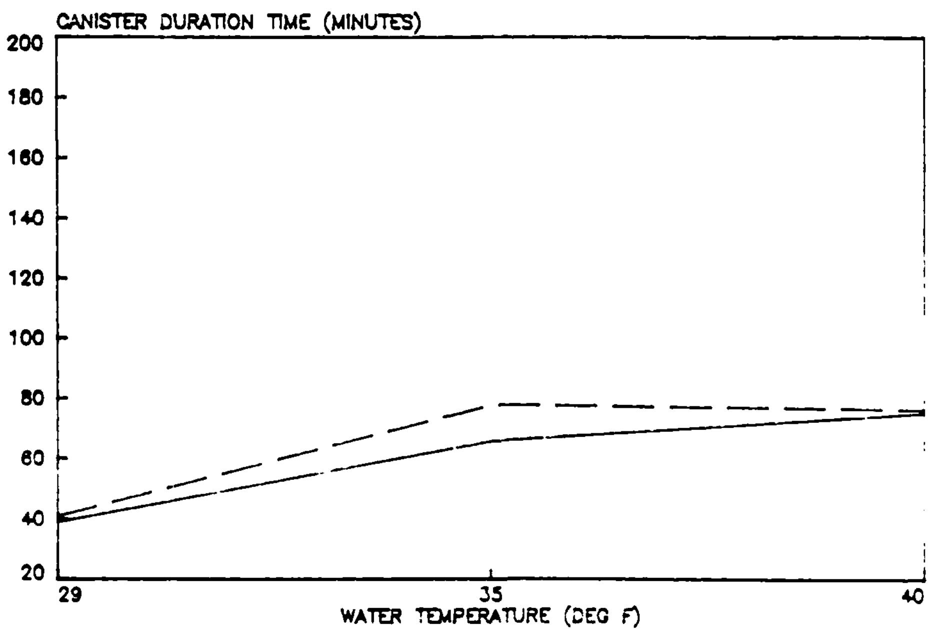


FIG.10 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
AGASORB (.9% SEV CO2)

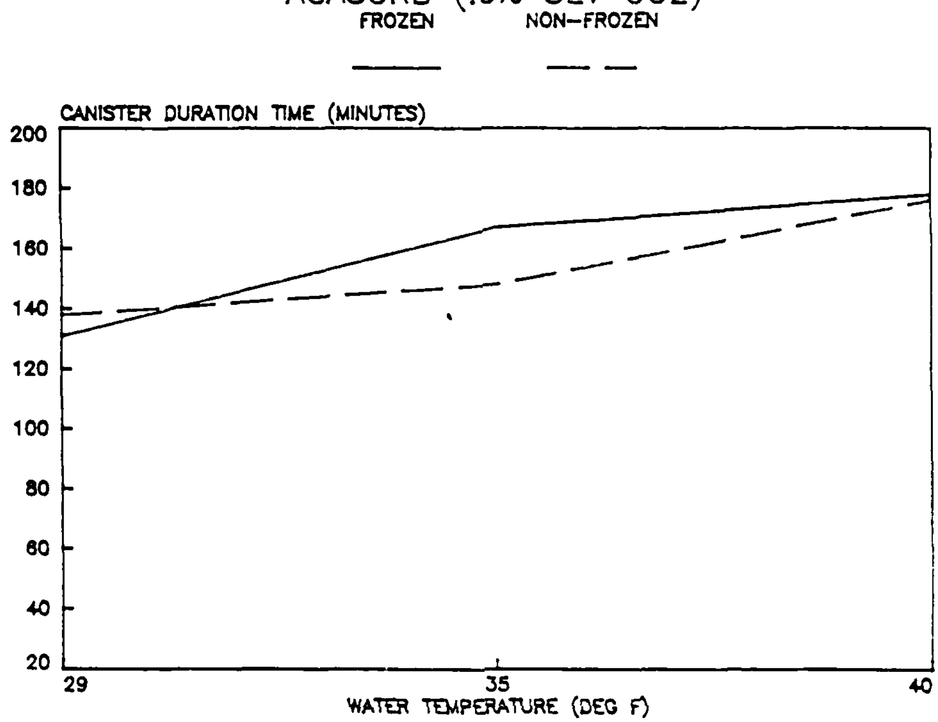


FIG.11 DRAEGER LAR V CANISTER CO2 ABSORBANT TEST
PROTOSORB (.9% SEV CO2)

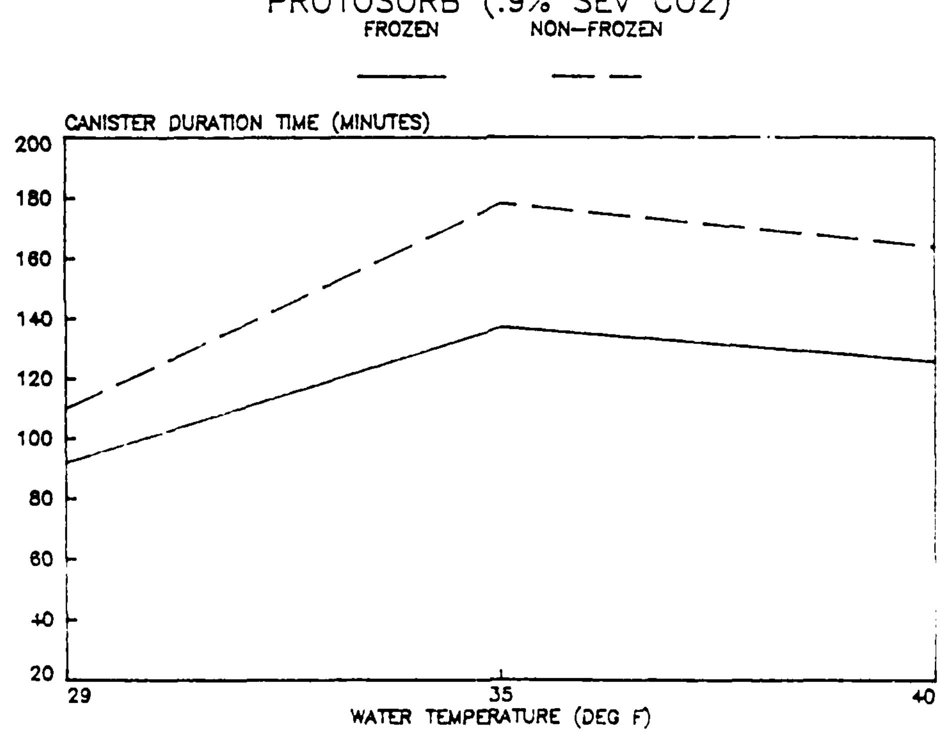
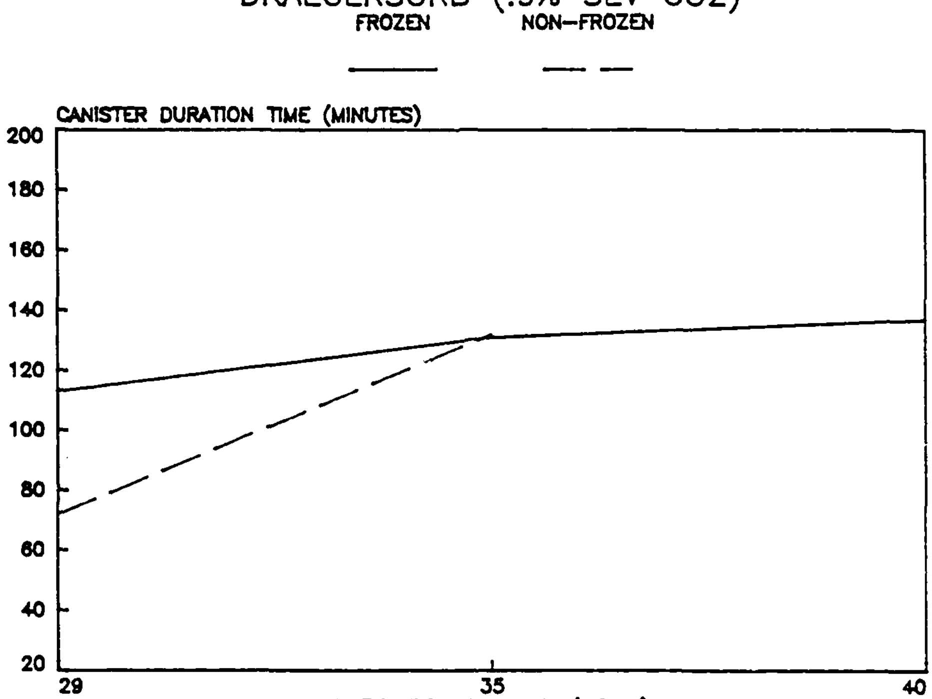


FIG.12 DRAEGER LAR V CANISTER CO2 DURATION TEST
DRAEGERSORB (.9% SEV CO2)



* 40 DEG F NON-FROZEN DATA NOT TAKEN

APPENDIX F

CANISTER OUTLET CO_2 LEVEL VS TIME

Data for canister duration (% SEV vs time) is contained in this appendix for all five absorbents tested. One plot of each absorbent at each temperature is included. Test and work cycles are readily observed as continuing throughout the test. Canister breakthrough is considered to occur at 0.50% SEV. Data is gathered beyond this point to more fully examine the operational limits of the equipment.

KEY:

Figure 13: AGASORB Canister Duration: 29°F Water Temperature

Figure 14: AGASORB Canister Duration: 35°F Water Temperature

Figure 15: AGASORB Canister Duration: 40°F Water Temperature

Figure 16: DRAEGERSORB Canister Duration: 29°F Water Temperature

Figure 17: DRAEGERSORB Canister Duration: 35°F Water Temperature

Figure 18: DRAEGERSORB Canister Duration: 40°F Water Temperature

Figure 19: DIVEASORB Canister Duration: 29°F Water Temperature

Figure 20: DIVEASORB Canister Duration: 35°F Water Temperature

Figure 21: DIVEASORB Canister Duration: 40°F Water Temperature

Figure 22: HP SODASORB Canister Duration: 29°F Water Temperature

Figure 23: HP SODASORB Canister Duration: 35°F Water Temperature

Figure 24: HP SODASORB Canister Duration: 40°F Water Temperature

Figure 25: PROTOSORB Canister Duration: 29°F Water Temperature

Figure 26: PROTOSORB Canister Duration: 35°F Water Temperature

Figure 27: PROTOSORB Canister Duration: 40°F Water Temperature

CANISTER OUTLET CO_2 LEVEL .VS. TIME

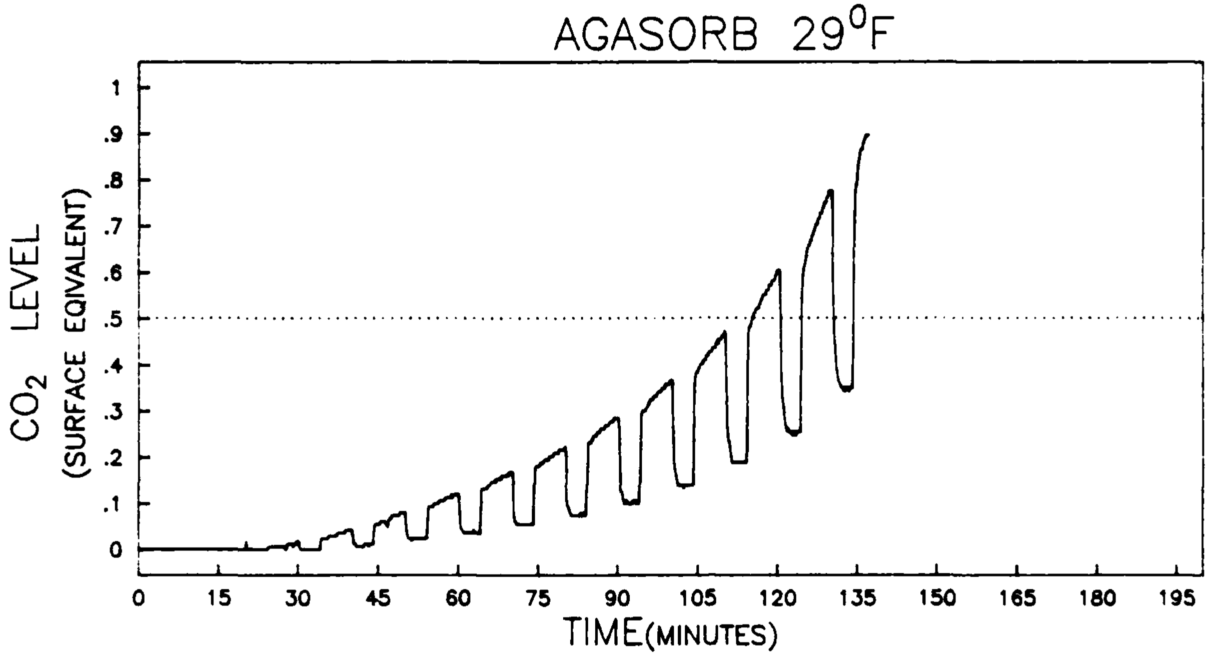


FIGURE #13

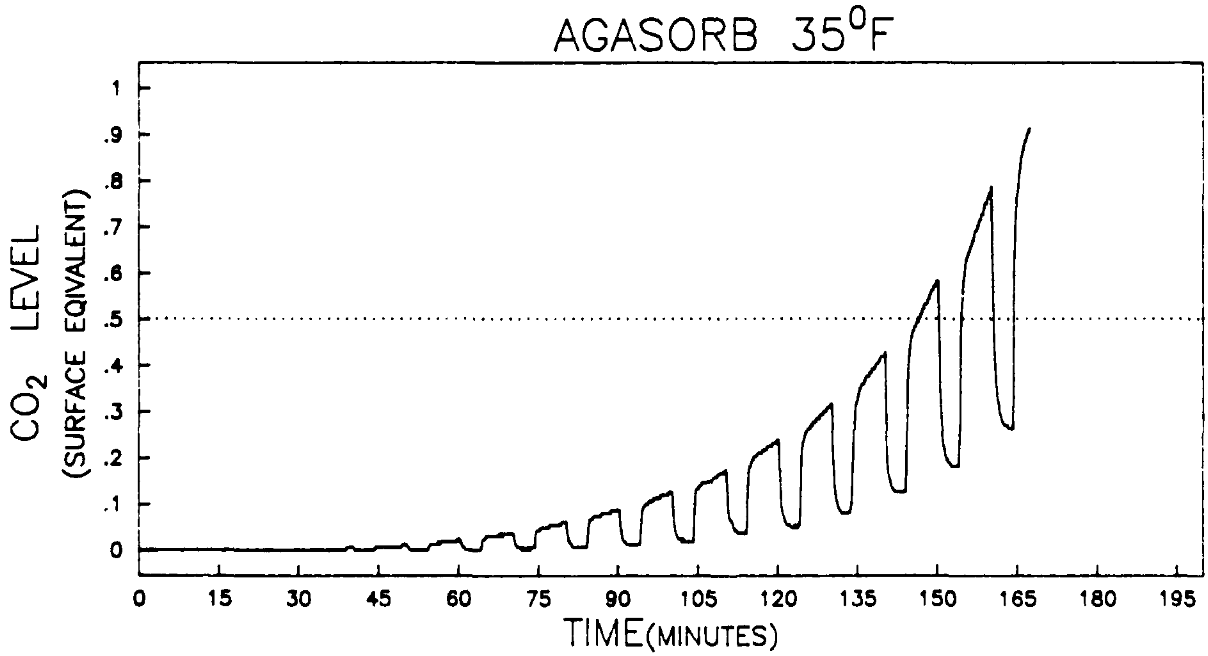


FIGURE #14

CANISTER OUTLET CO_2 LEVEL .VS. TIME

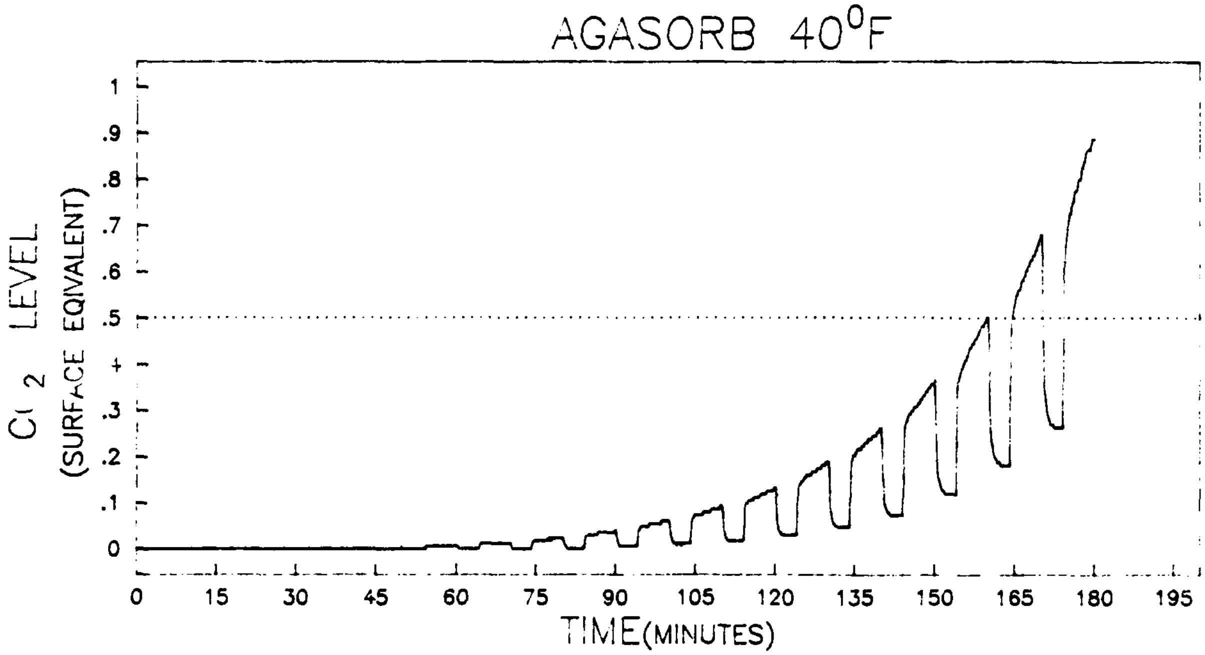


FIGURE #15

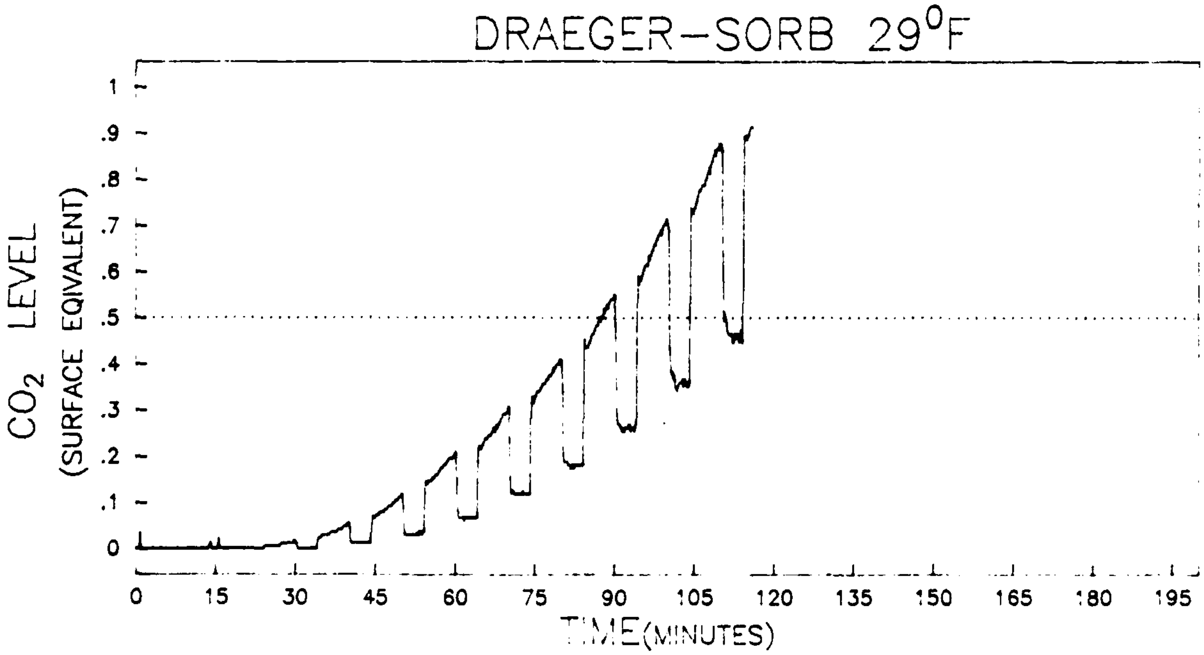


FIGURE #16

CANISTER OUTLET CO_2 LEVEL .VS. TIME

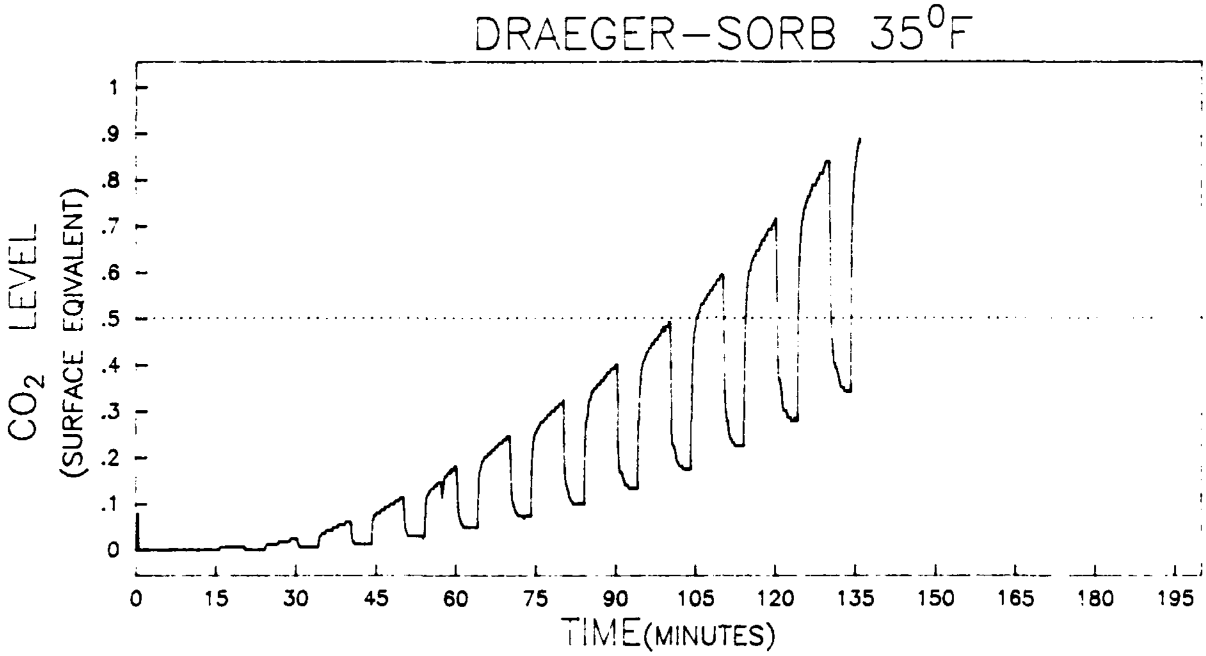


FIGURE #17

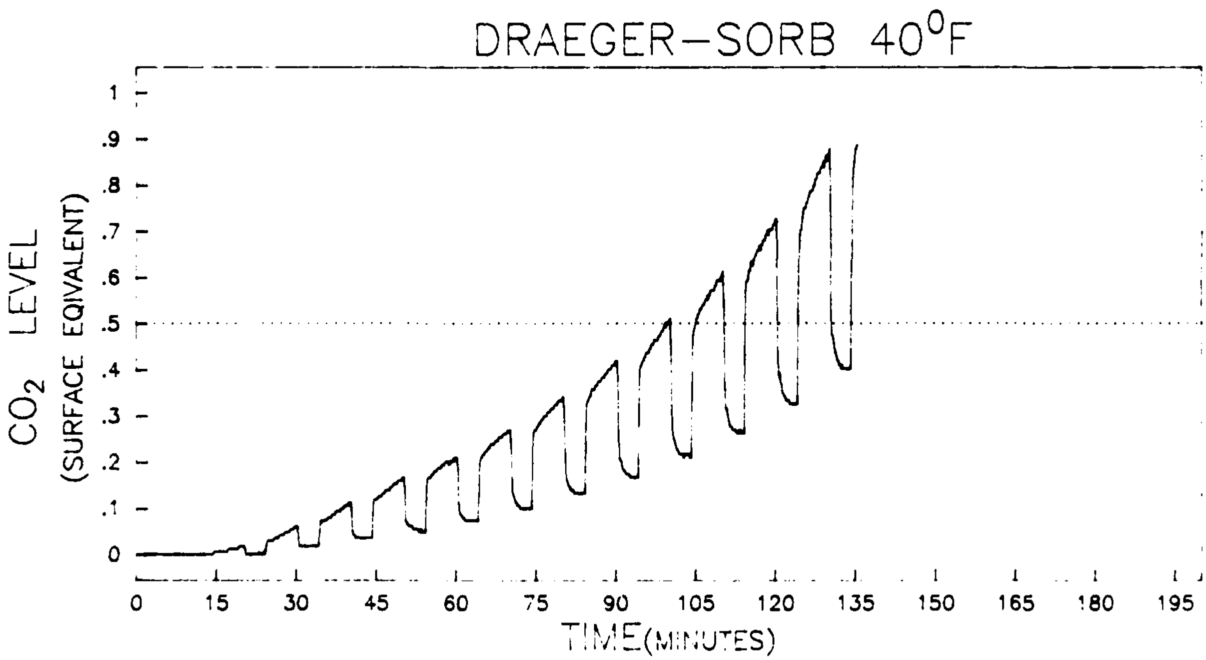


FIGURE #18

CANISTER OUTLET CO_2 LEVEL .VS. TIME

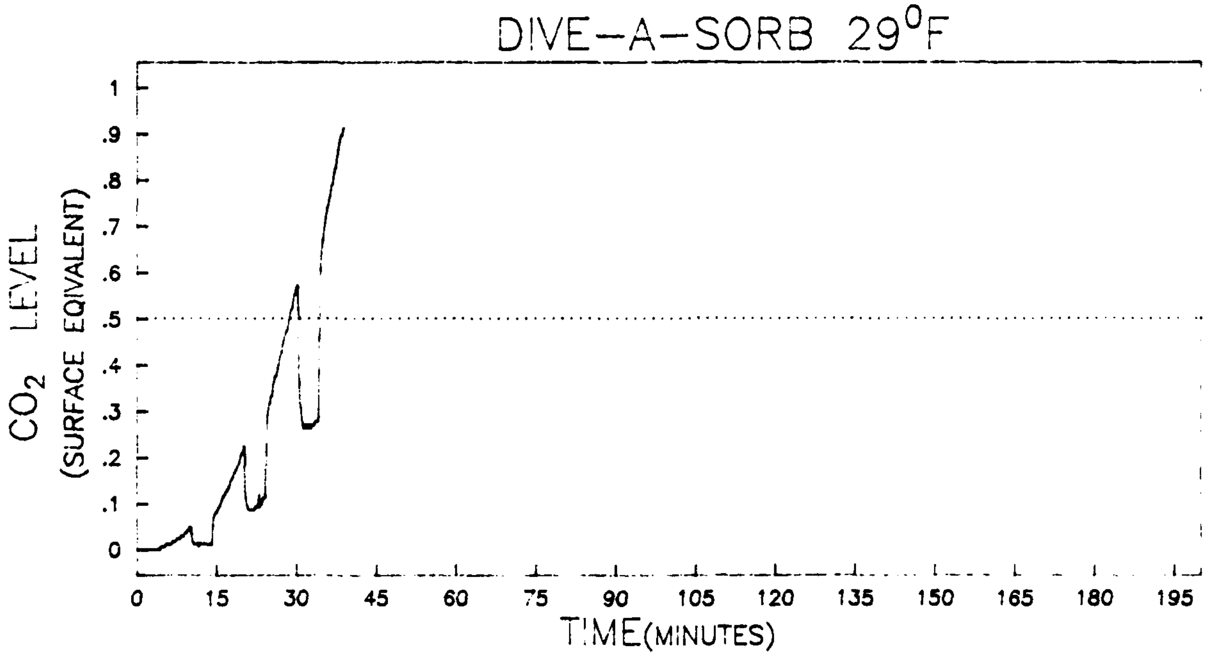


FIGURE #19

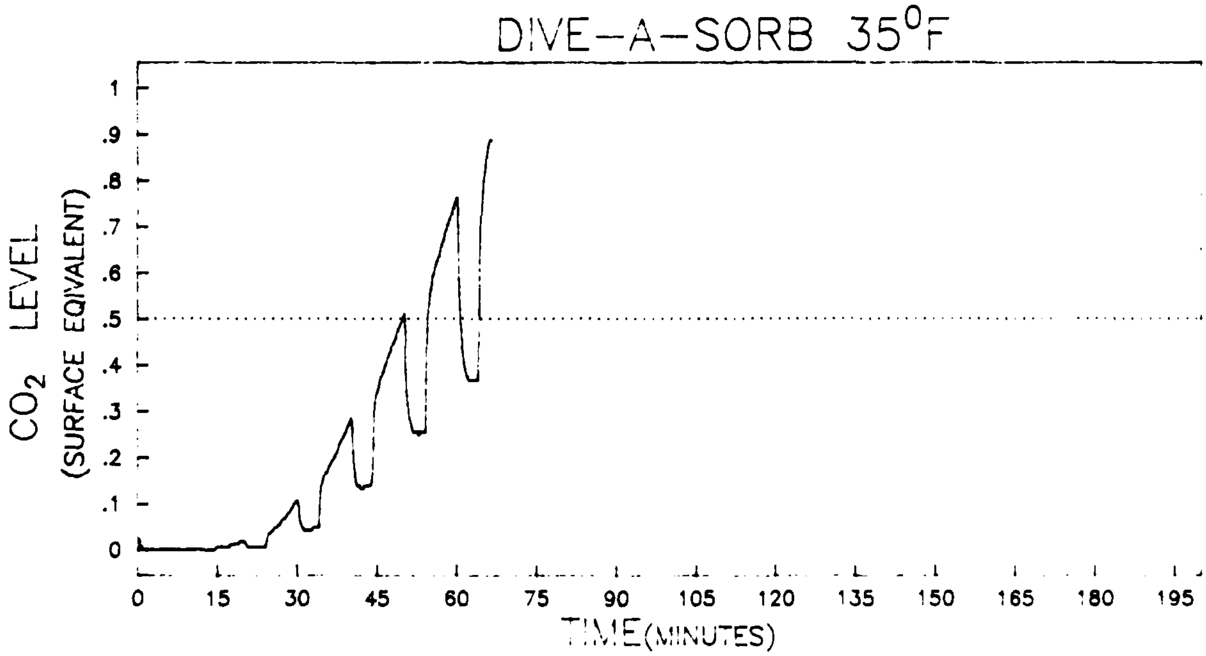


FIGURE #20

CANISTER OUTLET CO_2 LEVEL .VS. TIME

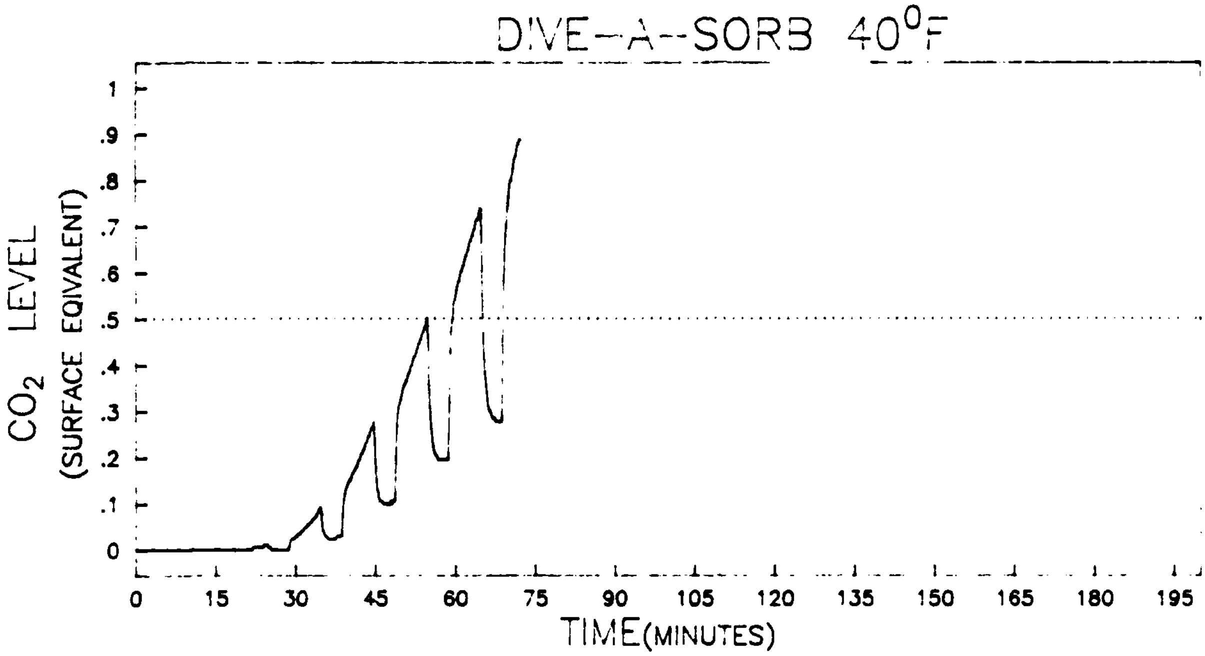


FIGURE #21

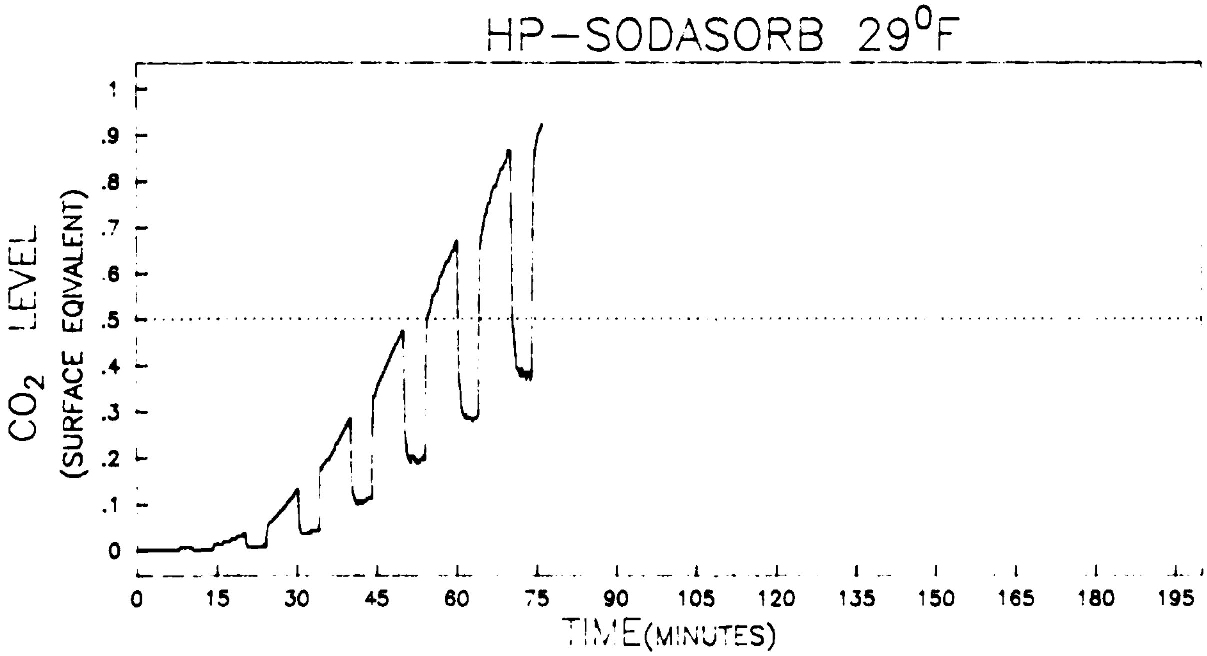


FIGURE #22

CANISTER OUTLET CO_2 LEVEL .VS. TIME

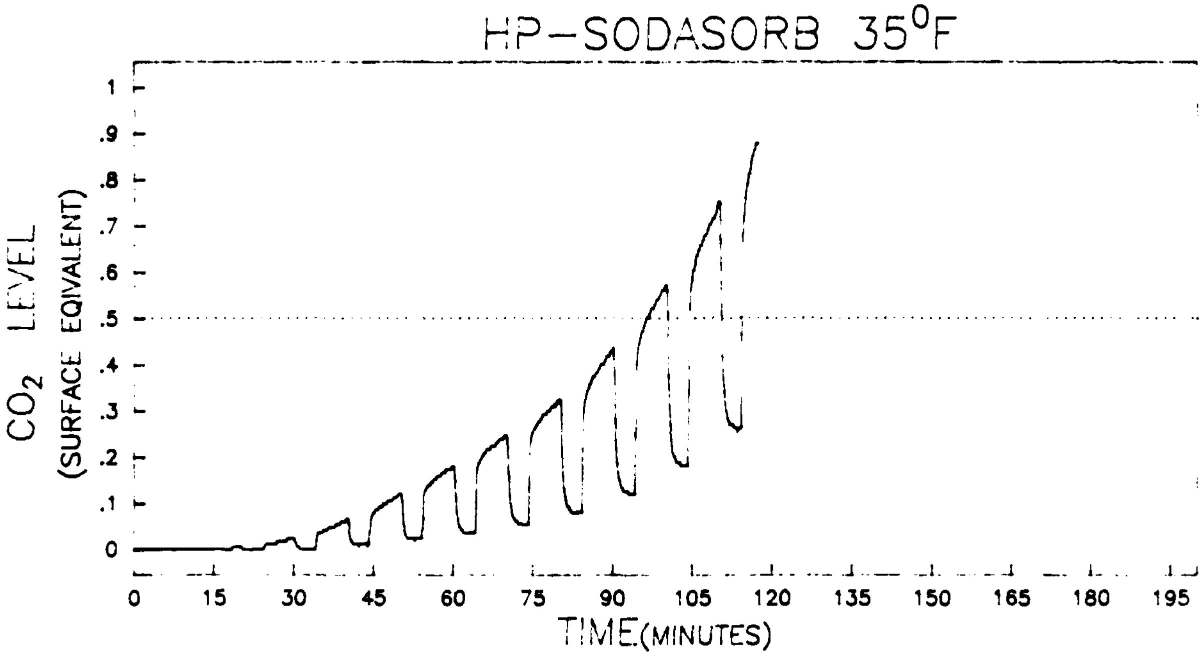


FIGURE #23

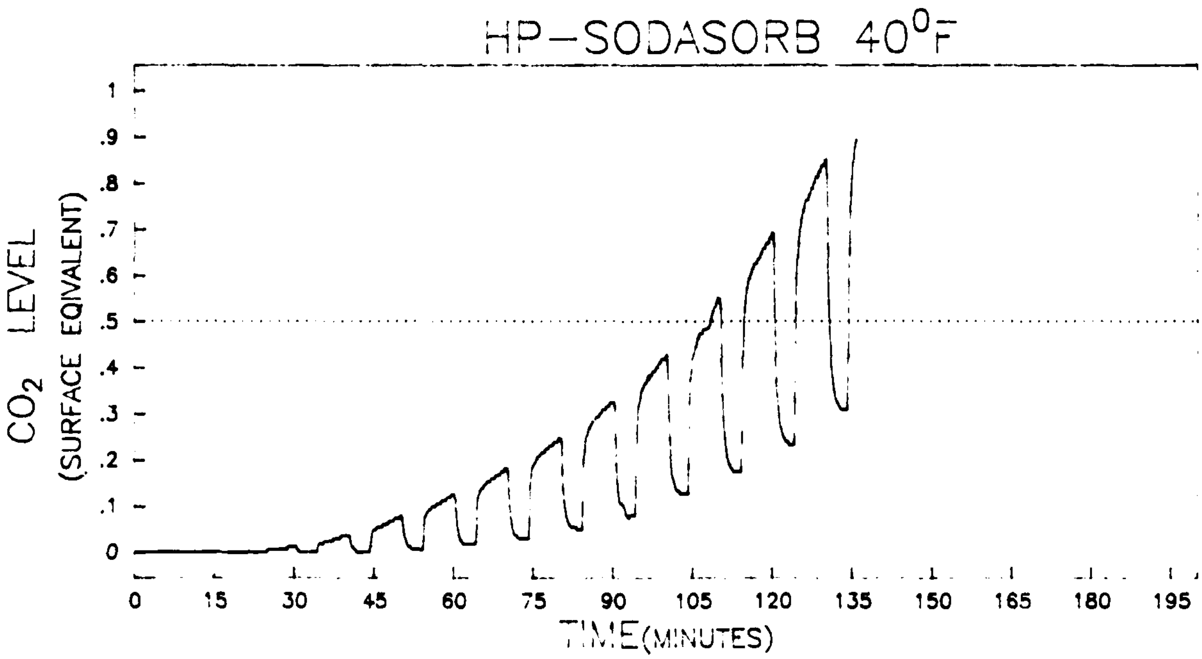


FIGURE #24

CANISTER OUTLET CO_2 LEVEL .VS. TIME

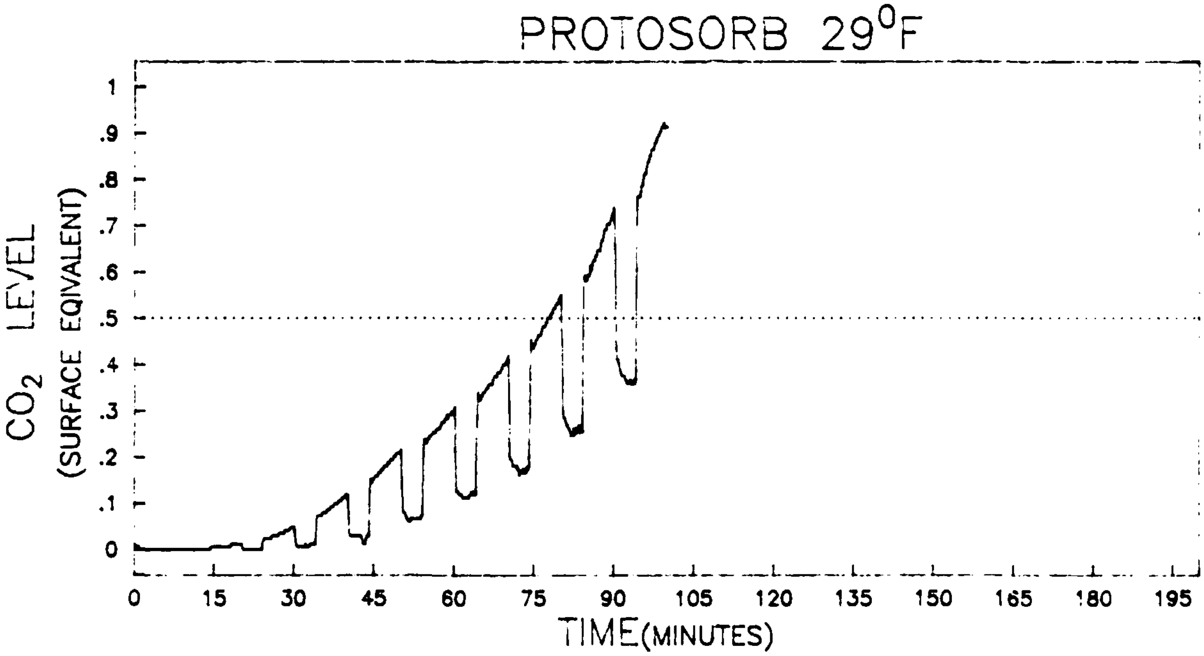


FIGURE #25

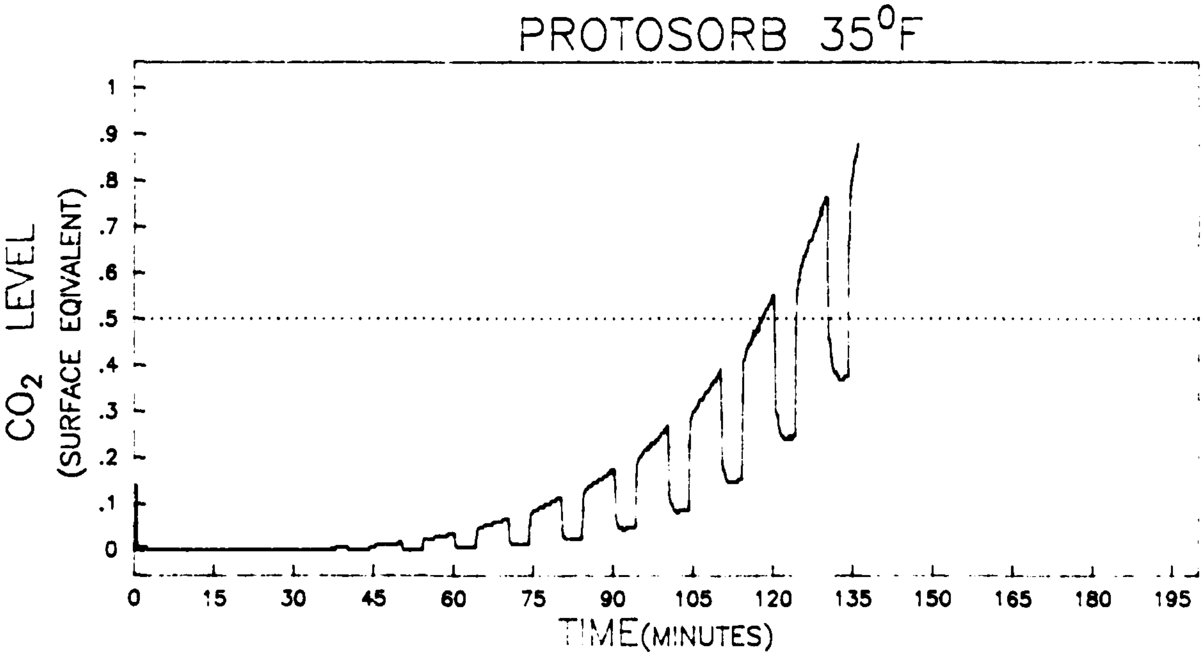


FIGURE #26

CANISTER OUTLET CO_2 LEVEL .VS. TIME

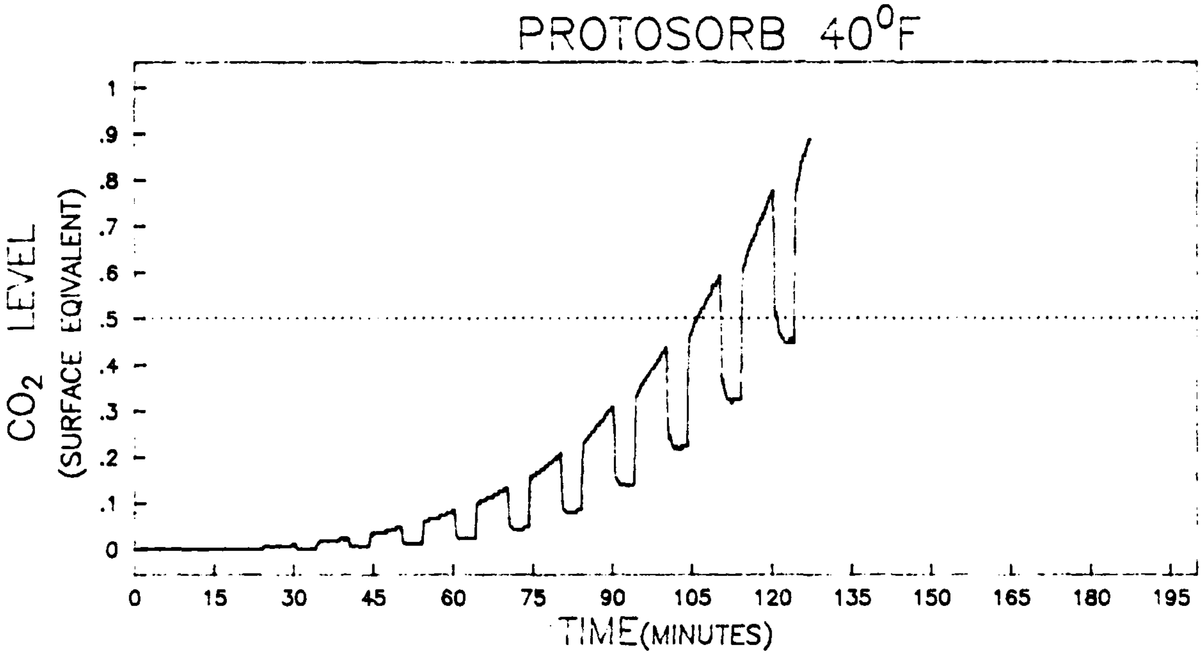


FIGURE #27

APPENDIX G

CANISTER BED TEMPERATURE VS TIME

Canister bed temperatures were monitored in three locations during each canister duration test. Representative plots of canister bed temperature vs time are provided for each CO_2 absorbent tested at each test temperature.

KEY:

CANISTER BED TEMPERATURE .VS. TIME

AGASORB 29°F

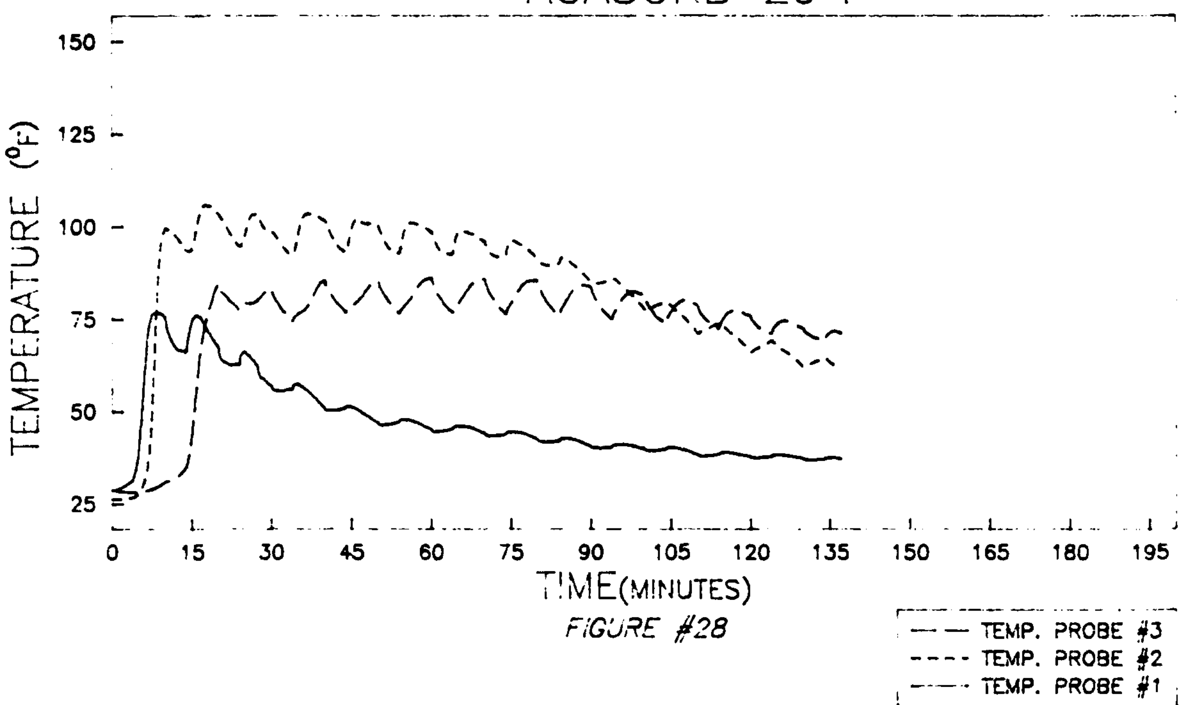


FIGURE #28

AGASORB 35°F

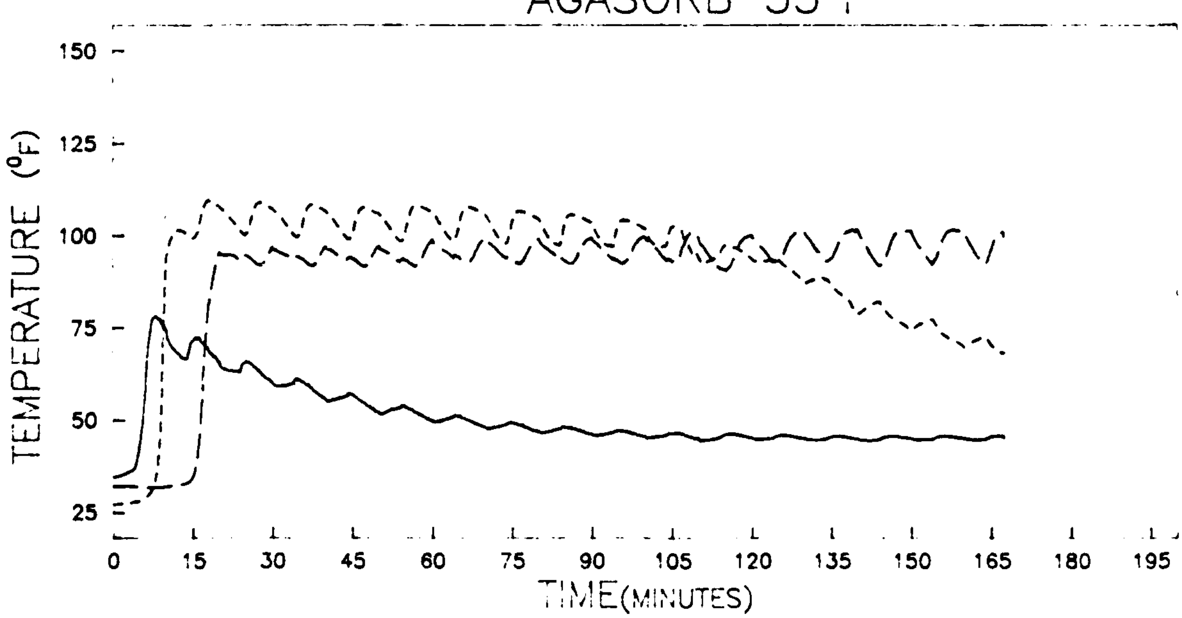


FIGURE #29

CANISTER BED TEMPERATURE .VS. TIME

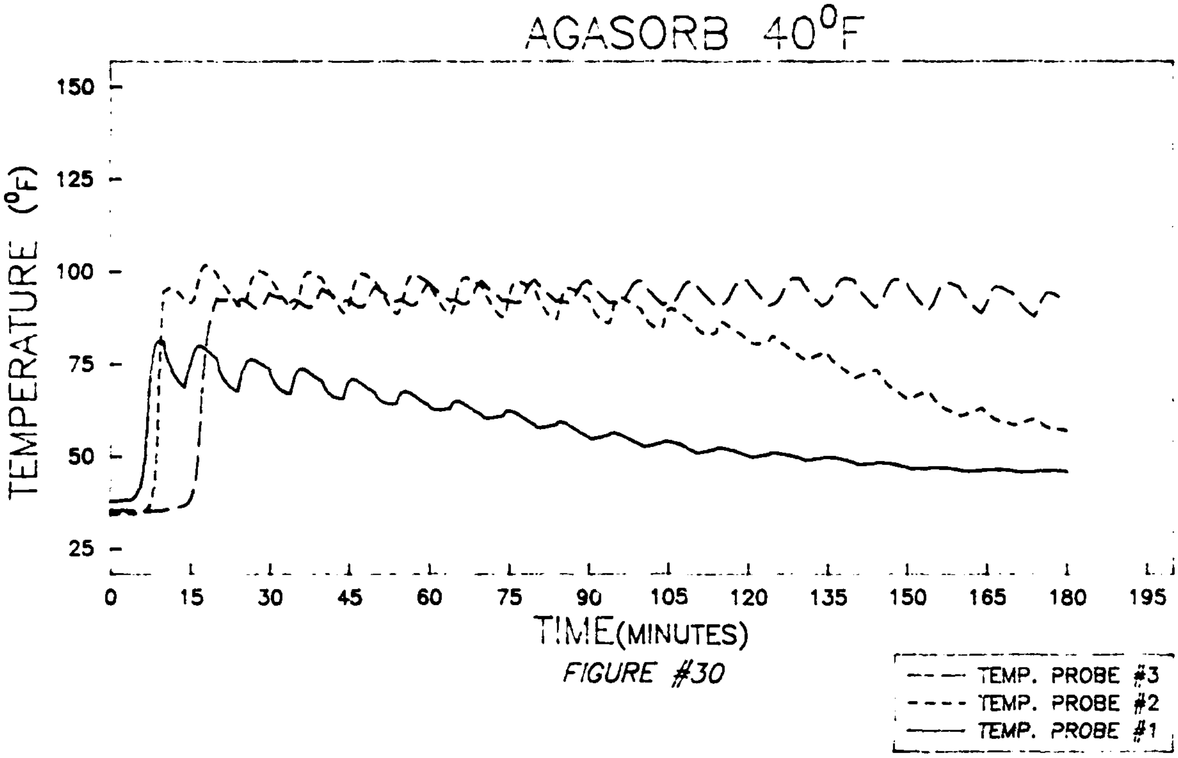


FIGURE #30

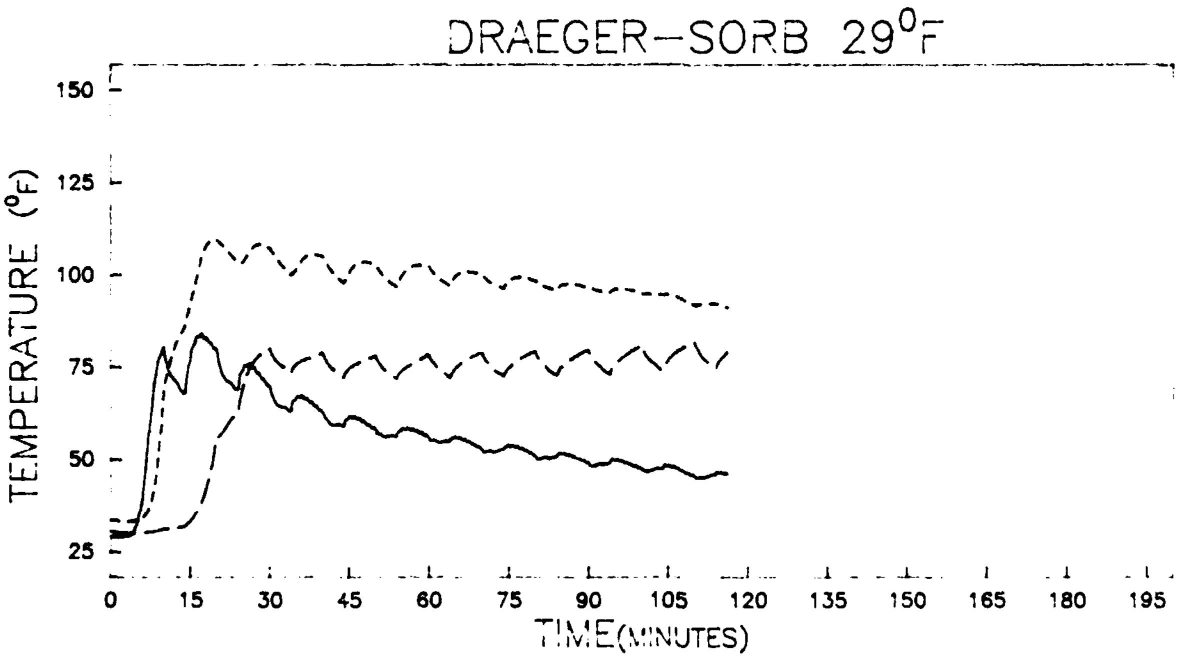


FIGURE #31

CANISTER BED TEMPERATURE .VS. TIME

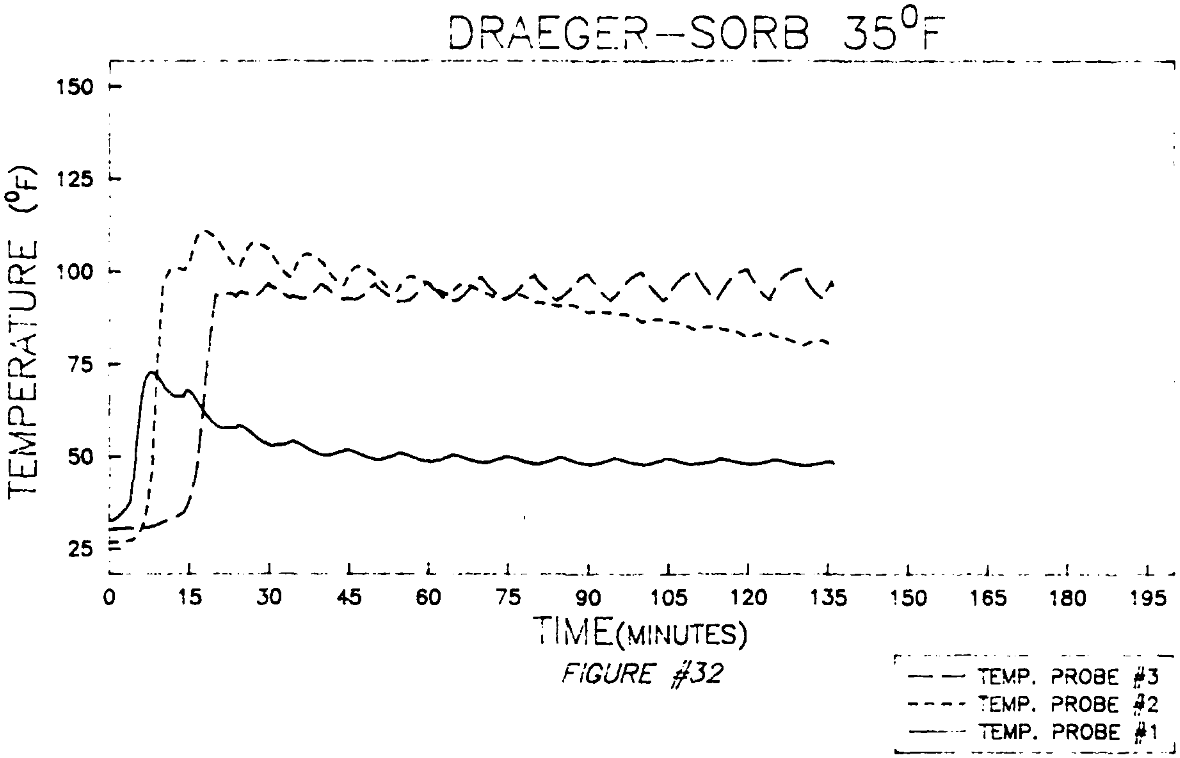


FIGURE #32

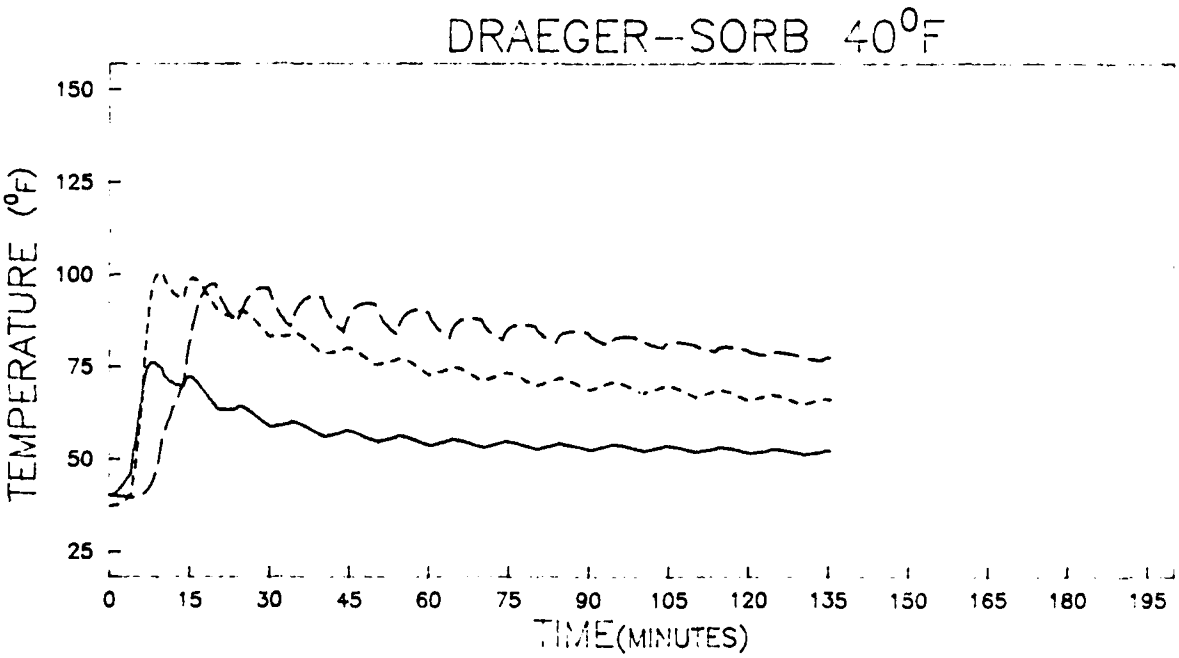


FIGURE #33

CANISTER BED TEMPERATURE .VS. TIME

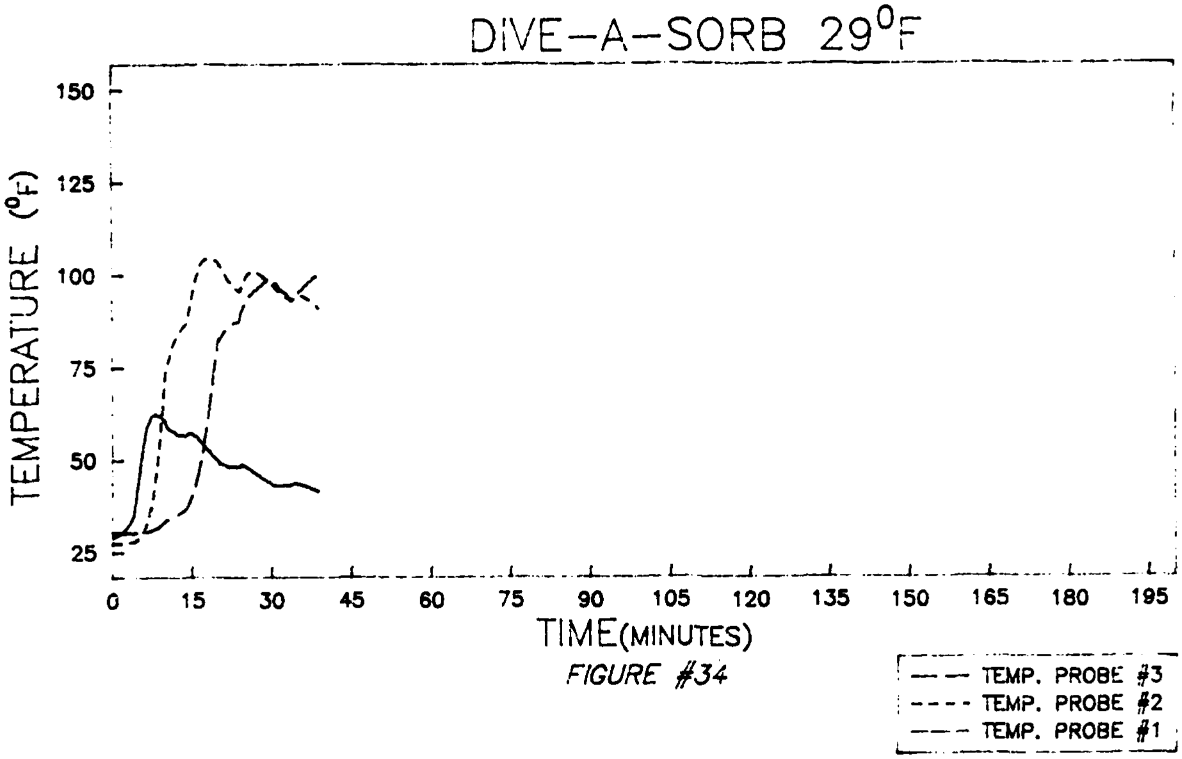


FIGURE #34

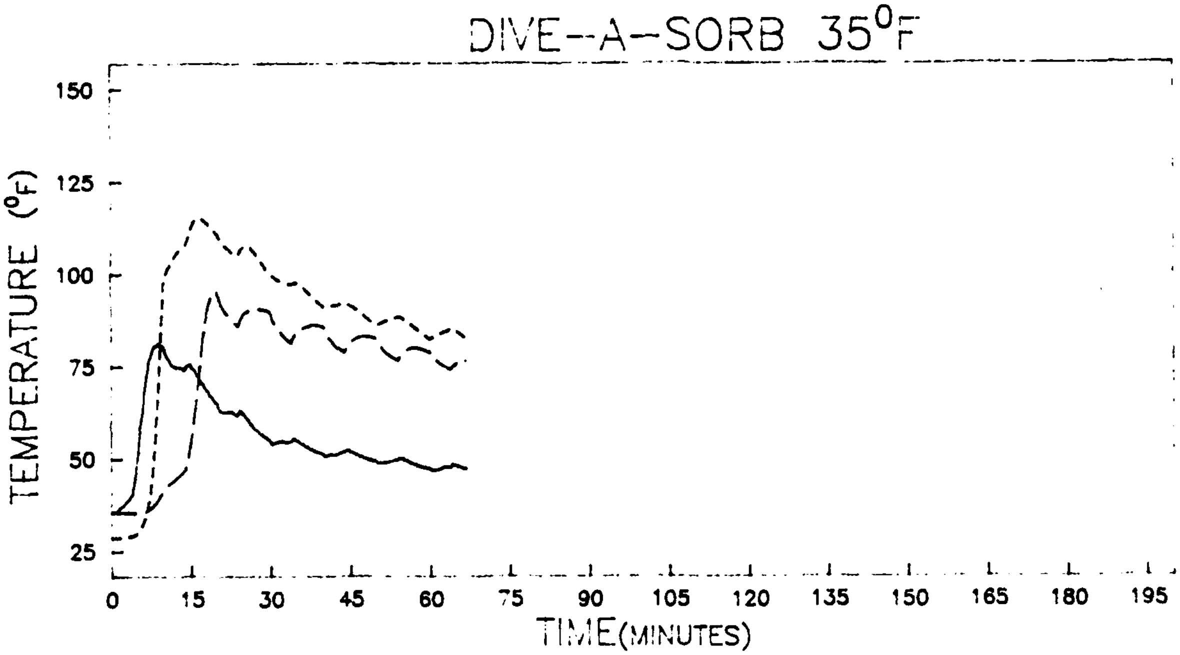


FIGURE #35

CANISTER BED TEMPERATURE .VS. TIME

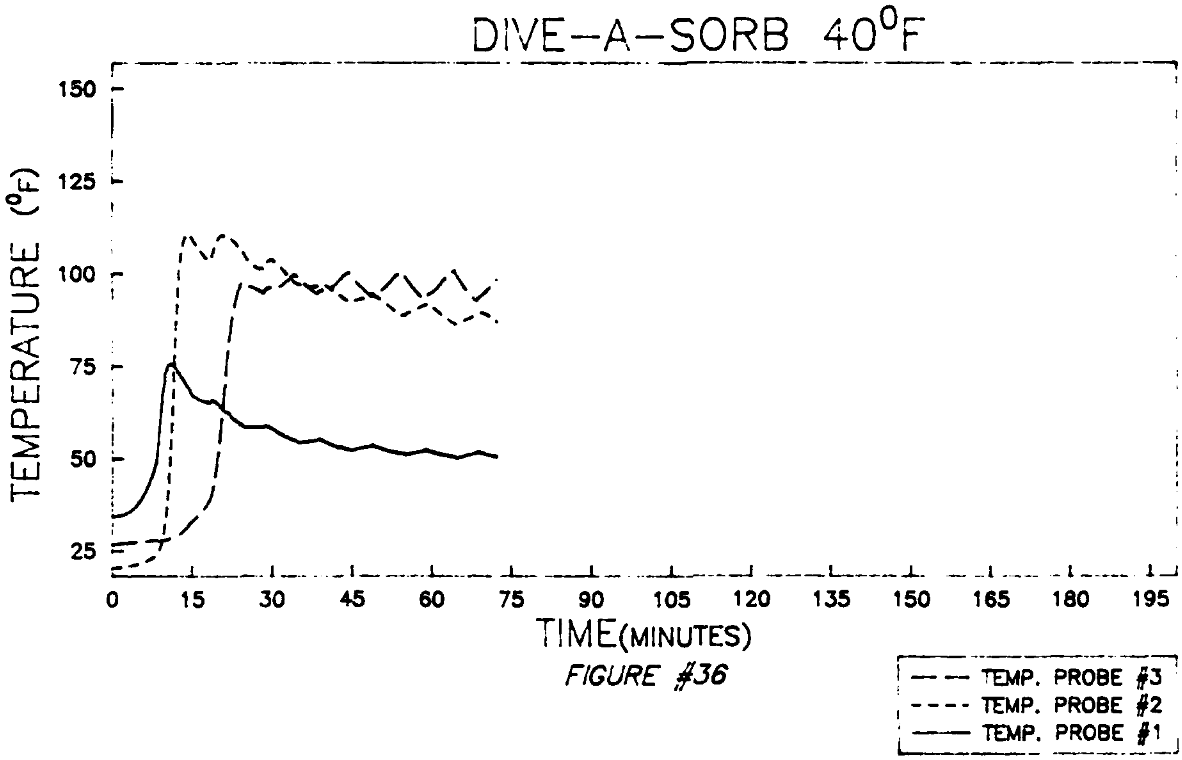


FIGURE #36

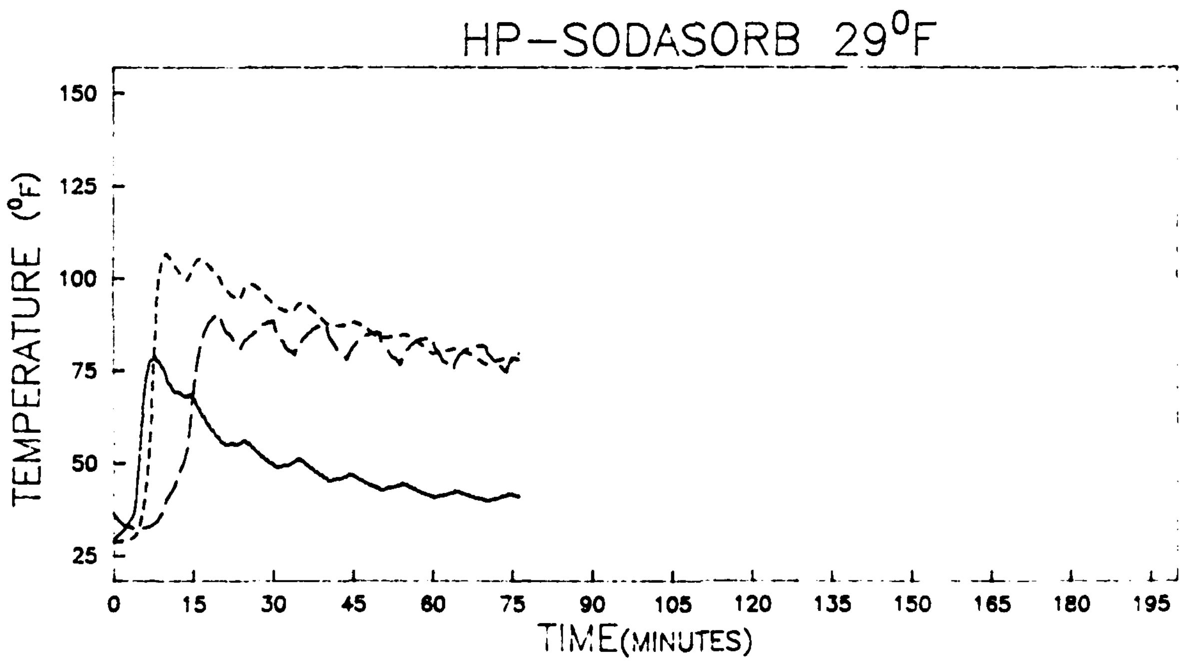


FIGURE #37

CANISTER BED TEMPERATURE .VS. TIME

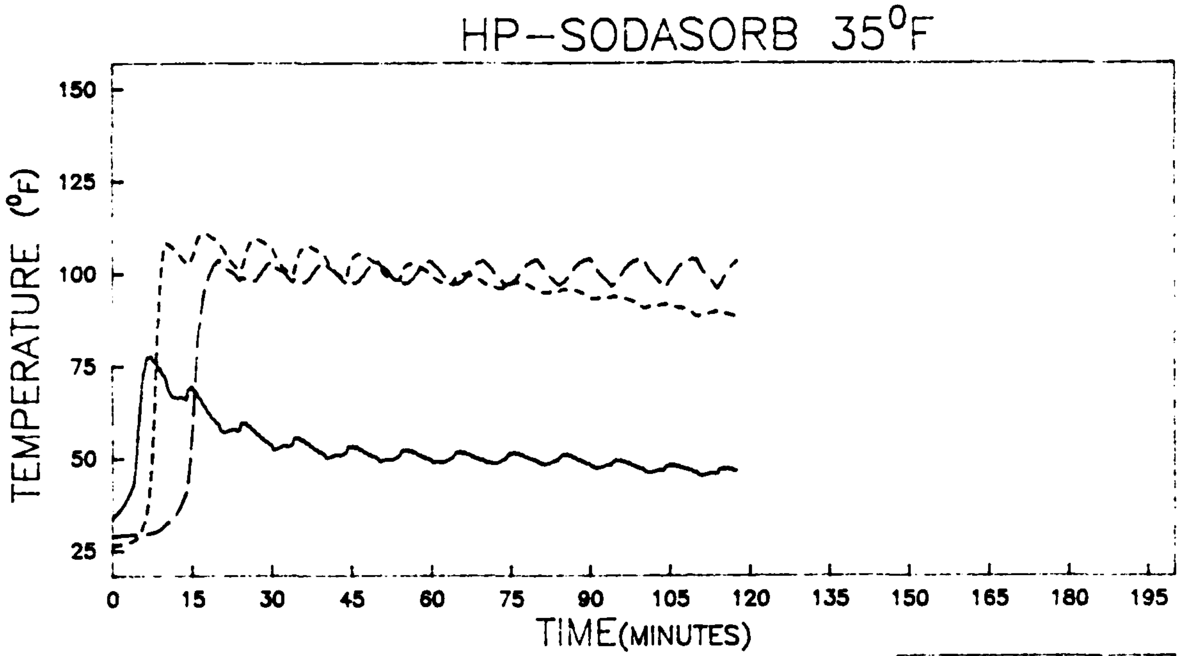


FIGURE #38

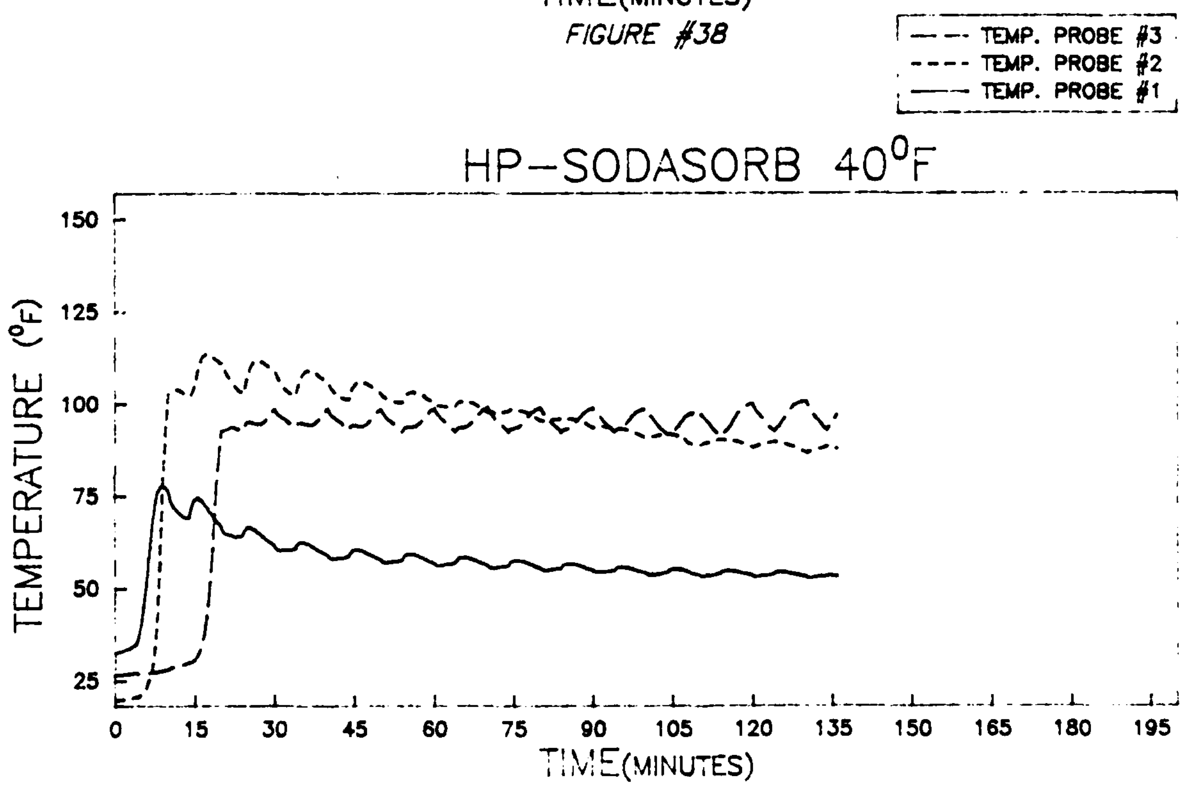


FIGURE #39

CANISTER BED TEMPERATURE .VS. TIME

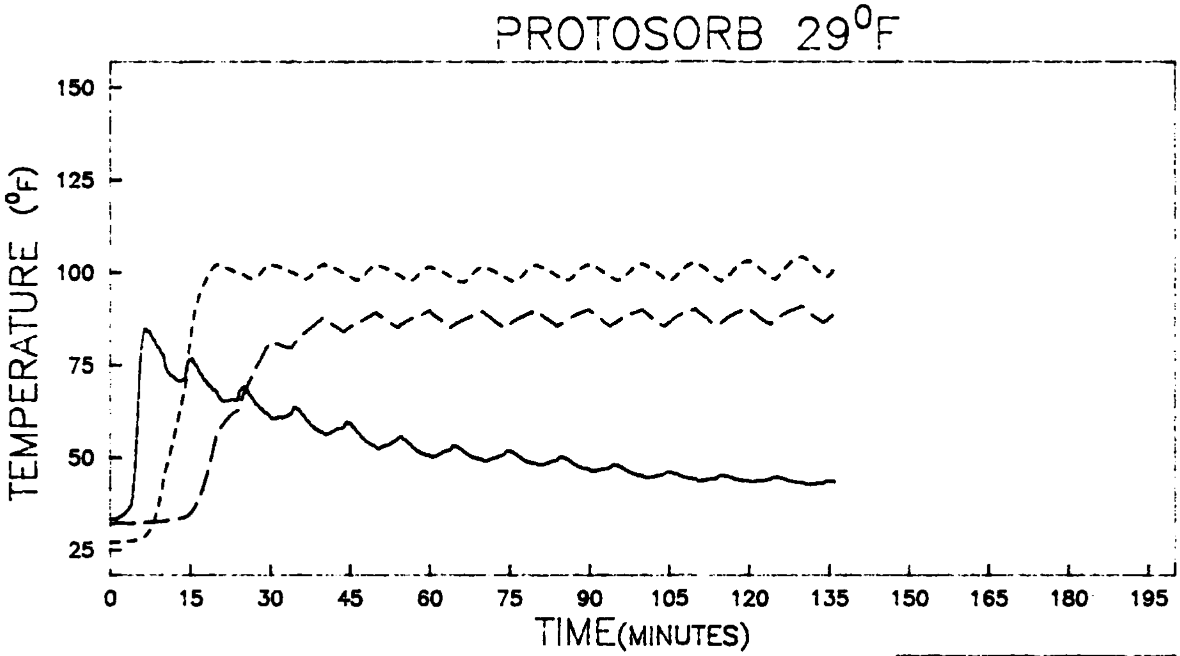
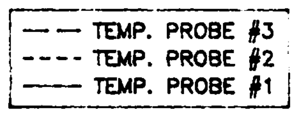


FIGURE #40



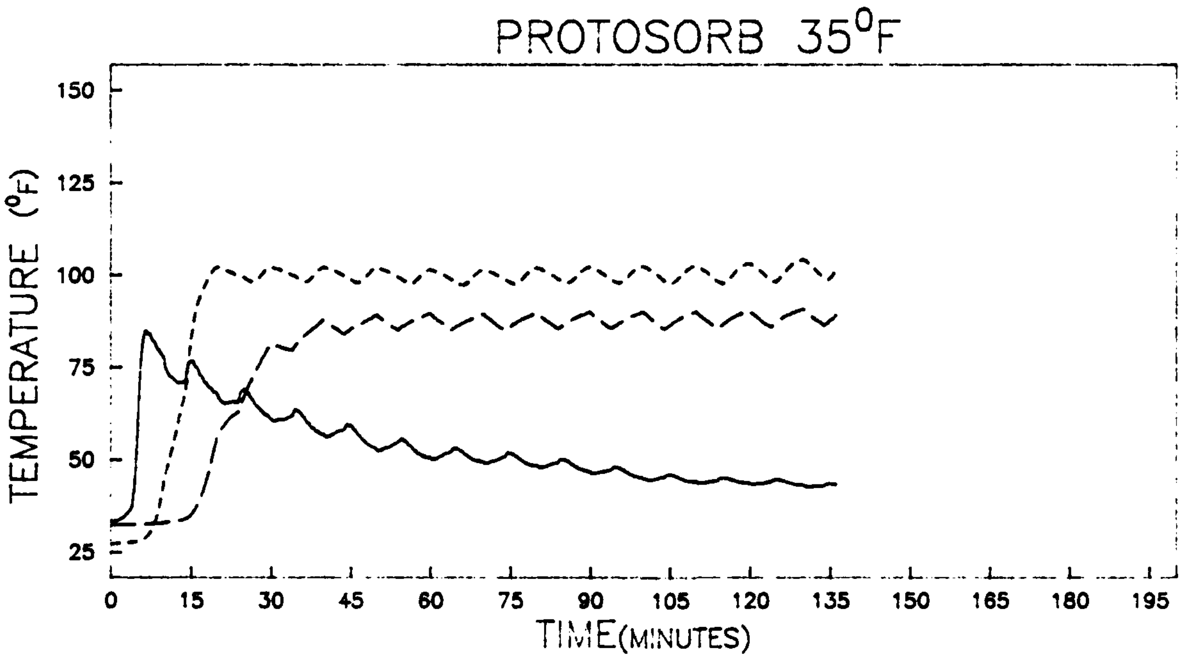


FIGURE #41

CANISTER BED TEMPERATURE .VS. TIME

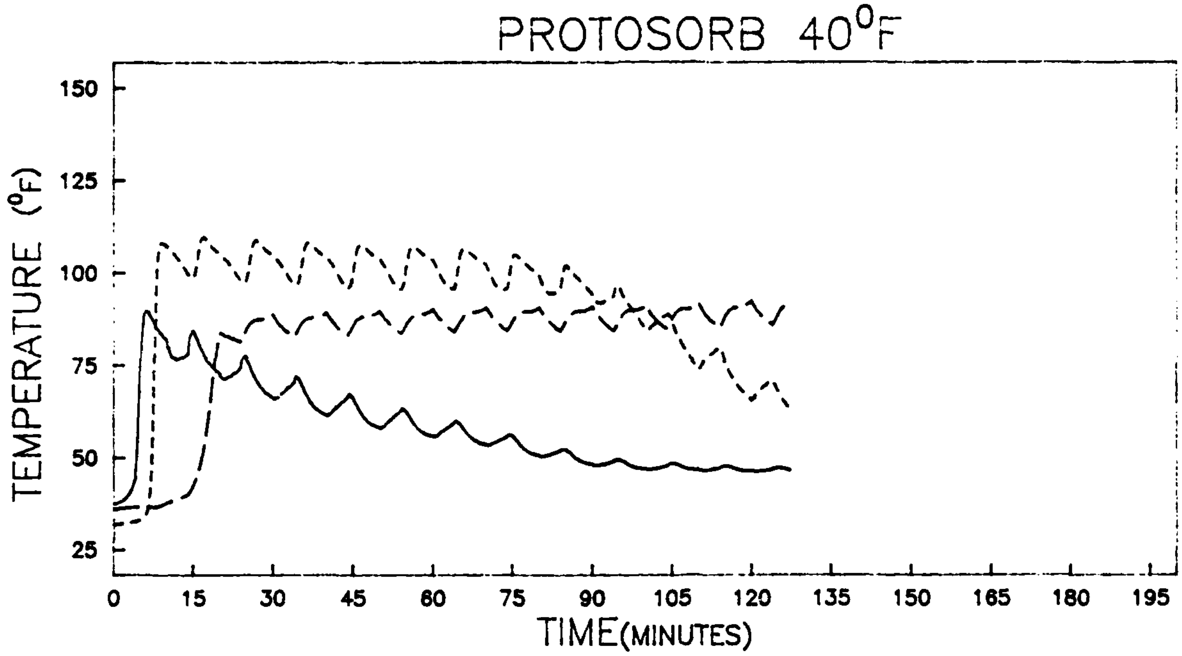


FIGURE #42

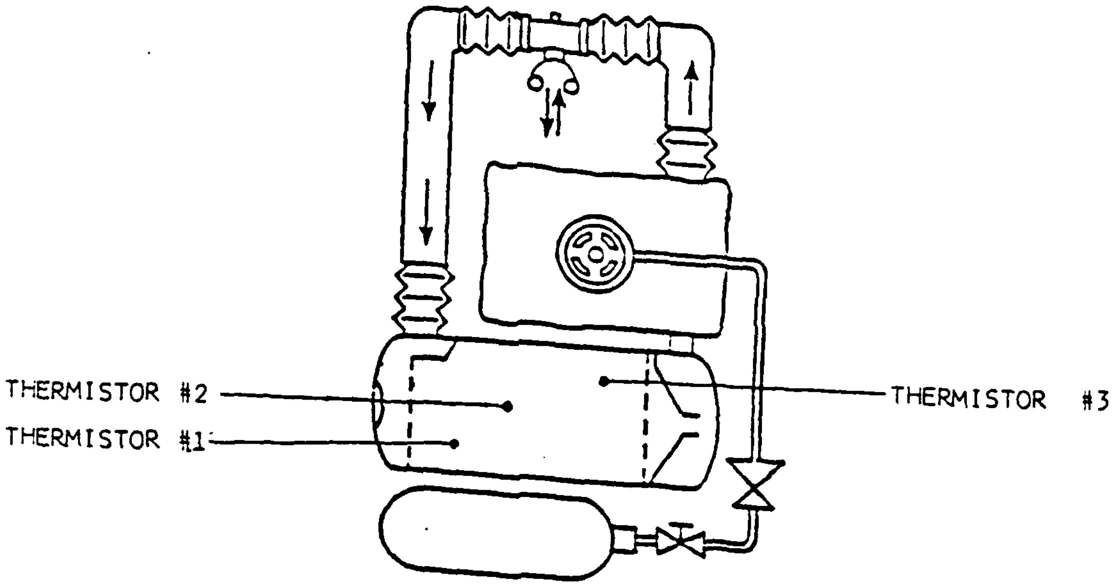


FIGURE 43. THERMISTOR PLACEMENT

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